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PRODUCTION ENGINEERING TEST OF GUIDED MISSILE

XM5E3 WARHEAD (U)

C-113 3213

First Report on Project No. PA1/58

(Picatinny Arsenal TPR No. D-77 (C))

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PRODUCTION ENGINEERING TEST OF GUIDED MISSILE XM5E3
WARHEAD

(U)

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ABERDEEN PROVING GROUND
MARYLAND

AUTHORITY: ORDBB-DC4,
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Mr. ELSeiple/tsp

PRODUCTION ENGINEERING TEST OF GUIDED MISSILE,
XM5E3 WARHEAD (U)

First Report on Project No. PA1/58

Dates of Test: September to November 1959

ABSTRACT (C)

As a result of production engineering changes to reduce the cost of fabricating the inert parts of the XM5 warhead, three XM5E3 warheads incorporating the changes were subjected to fragmentation, blast and drop tests to determine whether the incorporations would detrimentally affect the established functional or safety requirements.

Fragmentation test results indicated that the mass distribution of the fragments of the XM5E3 warhead was comparable with that of the XM5E1 warhead. Initial fragment velocity from the XM5E3 warhead showed an increase of 315 feet per second over the XM5E1 warhead. The safety arming (S&A) liner and booster cavity, a one-piece design which provides the initial velocity from this section of the XM5E3 warhead, showed an increase of 500 feet per second over the XM5E1 warhead.

Previous blast test of the XM5 warheads showed that the flame front or jet stream caused the electronic gages to give erratic results. A new technique, tentatively called the photographic fence technique, was included to supplement the usual instrumentation. Results of the fence technique indicate blast pressures to be about 30 psi at a distance of 20 feet.

The XM5E3 warhead did not detonate when dropped onto armor plate from a height of 40 feet, but was rendered unserviceable.

Test results show that the incorporation of production engineering changes in the XM5E3 warhead did not detrimentally affect the established functional or safety requirements.

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It is recommended that the production engineering changes be adopted.

In future detonations of the XM5 warheads, electronic measurements of the blast should be made at a distance of 25 feet or greater.

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ANNEX

DRAWING OF WARHEAD, GUIDED MISSILE, XM5E3

INDIVIDUAL FRAGMENT WEIGHTS

AMMUNITION DATA CARDS

(The Annex is on file in the Technical Library, APG, for reference purposes. Copies of the Annex may be furnished to recipients of this report upon request.)

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1. (C) INTRODUCTION

The XM5 warhead design for the Hawk guided missile is roughly barrel-shaped. Approximately 1700 preformed steel fragments are cemented between two shells of resin-impregnated glass cloth. As a result of production engineering studies, several changes were made in the design of the warhead to reduce the cost of fabricating the inert parts. Figure 1 illustrates the present design of the XM5E3 warhead. A comparison of the component parts of the XM5E2 and the design changes made which resulted in the XM5E3 is given underneath the figure.

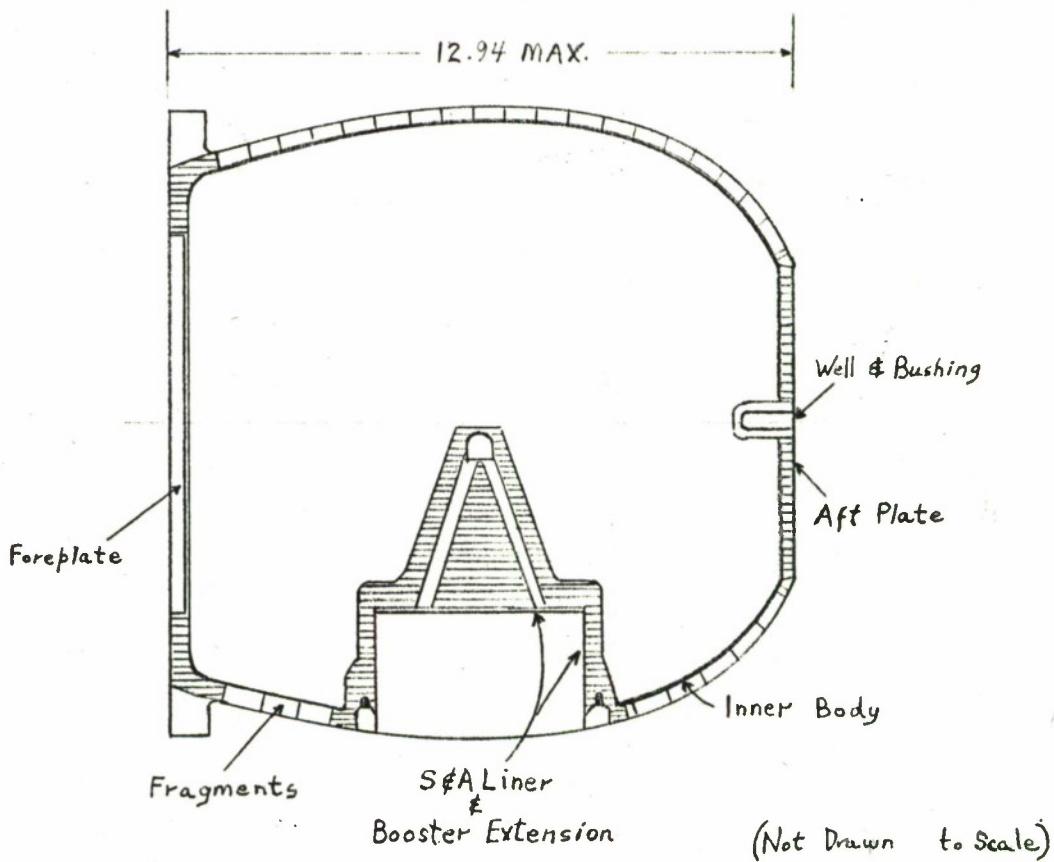


Figure 1 (U): XM5E3 Warhead Inert Parts Assembly.

XM5E2	XM5E3
Plastic laminated.	Outer Body Epoxy resin coating.
Aluminum.	Fore Plate Glass Fibre.
S&A Liner and Booster Extension Separate components..	One piece design.
Plastic laminated material.	Inner Body Glass fiber compound.

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The following components of the XM5E3 were fabricated in halves and then molded into an integral unit by a compression process:

After plate	Forward plate
Inner body	Forward reinforcement ring
Locator well	After reinforcement ring
Locator bushing	Helix fragment support

A test of the production engineering changes to the XM5E3 warhead was required prior to acceptance of the XM5E3 warhead to determine what detrimental effects, if any, would occur as a result of the production engineering changes. The XM5E3 warhead was required to produce fragment velocities, fragment distribution and blast pressures in a static test that were not significantly different from those obtained with the XM5E2 (reference APG Firing Record B-14172). In addition the warhead was required to withstand a 40-foot drop onto armor plate without detonation.

2. (C) DESCRIPTION OF MATERIEL

Warhead, Guided Missile, XM5E3, loaded with approximately 73 pounds of H-6 explosive, and boosted with 862 grains of RDX, Manufactured by Aerojet General Corporation, Lot No. 01, Units 15, 16 and 17.

The safety and arming cavity discussed throughout this report is an opening 5.59 inches long by 2.46 inches wide and 1.49 inches deep in the side of the warhead, into which the safety and arming fuze is inserted. The safety and arming fuze was not used during these tests. Aerojet Drawing No. 1-056386 in the Annex of this report shows the safety and arming cavity.

Ordnance Corps ammunition data and lot description sheets, appear in the Annex of this report.

3. DETAILS OF TEST

3.1 Drop Test

3.1.1 (U) Procedure. In conducting this test a drop tower (Figure 2) 60 feet in height, equipped with blocks, hooks and a 700-foot cable, was used. The warhead was attached to the hook by means of a manila rope so that the impact would occur on the safety and arming cavity. A shearing charge (blasting cap with Composition C-3) was attached to the manila rope midway between the hook and warhead (Figure 3). Lead wires were attached to the blasting cap. A hoist raised the warhead to a height of 40 feet. The shearing charge was detonated by energizing the firing line by means of a blasting machine; this severed the manila rope, allowing the warhead to fall freely into the drop pit (Figure 4) and impact on the armor plate (10 feet by 10 feet by 3 inches in size).

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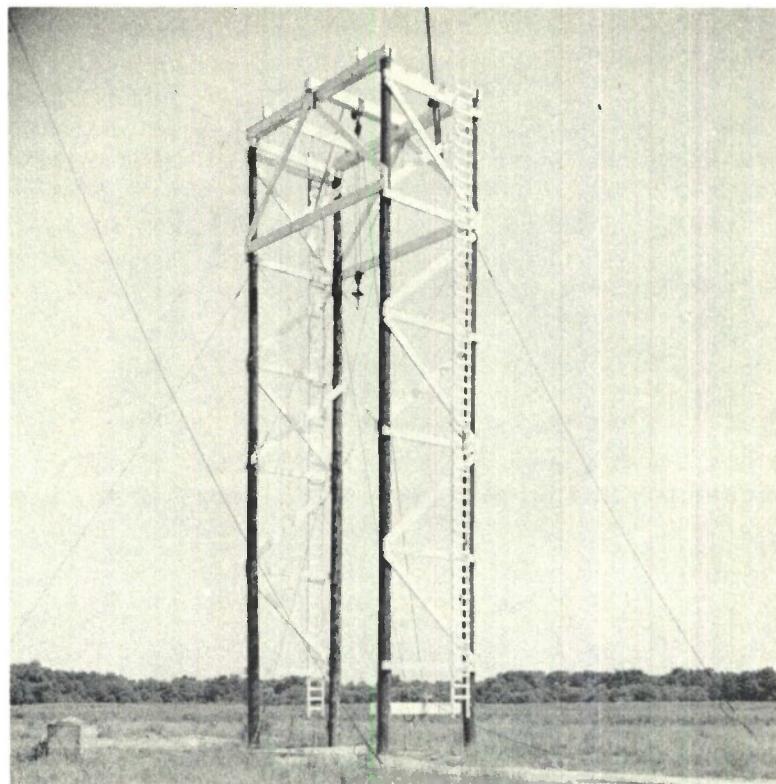


Figure 2 - A90501 (U): Drop Test Tower.

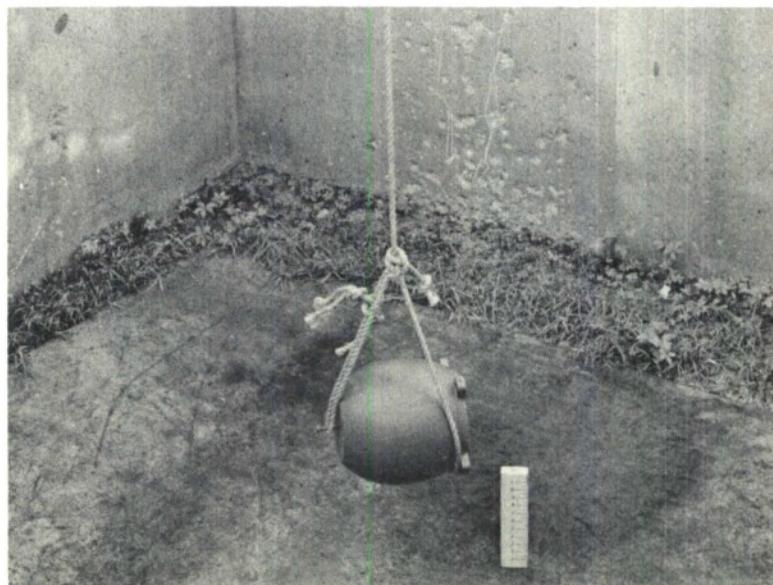


Figure 3 - 59T3255: Test Arena and Warhead Rigged for Drop to Impact on S and A Cavity.

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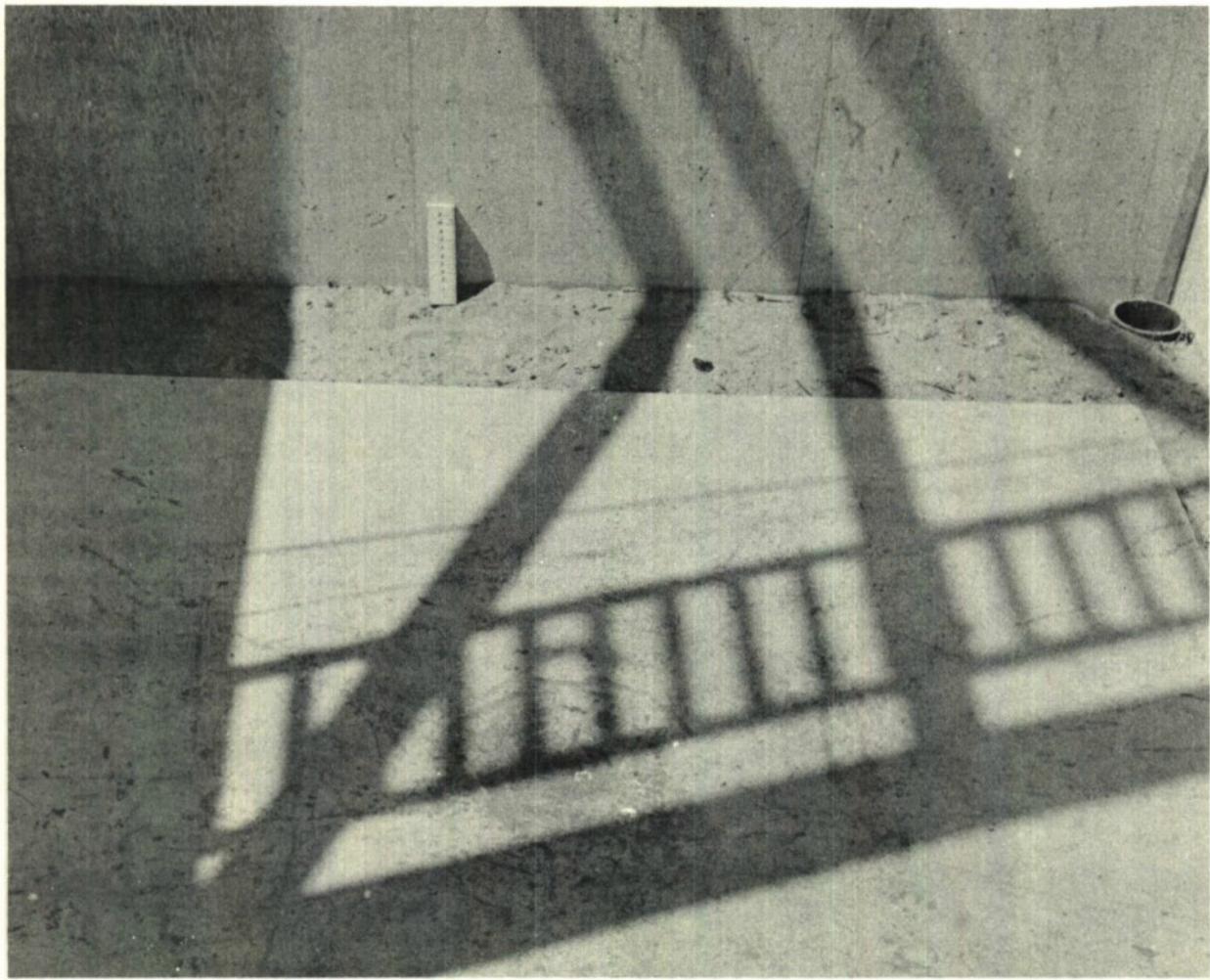


Figure 4 - A90502 (U): Drop Pit.

After a waiting period of 15 minutes, the warhead was examined for deformation, fractures and functioning of the explosive.

3.1.2 (C) Results. The warhead did not detonate when dropped from a height of 40 feet. Impact occurred with the longitudinal axis of the warhead approximately 45 degrees from horizontal with the safety and arming cavity facing down. The warhead broke into several pieces as shown in Figure 5. Explosive and fragments were scattered over the bottom of the drop pit (Figure 6). The safety and arming liner and booster extension broke into numerous pieces, as shown in Figure 7. The warhead was rendered unserviceable.

The results of the drop test of the XM5 warhead (reference APG Firing Record B-14142) showed that no detonation occurred when the warhead impacted on the armor plate from a height of 40 feet. The outer and inner case broke, expelling fragments and exposing explosive. The warheads were rendered unserviceable.

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Figure 5 - 59T3257: Damaged Warhead; Broken Booster and Crumpled Explosives, after Impact Onto Armor Plate from a Height of 40 Feet.

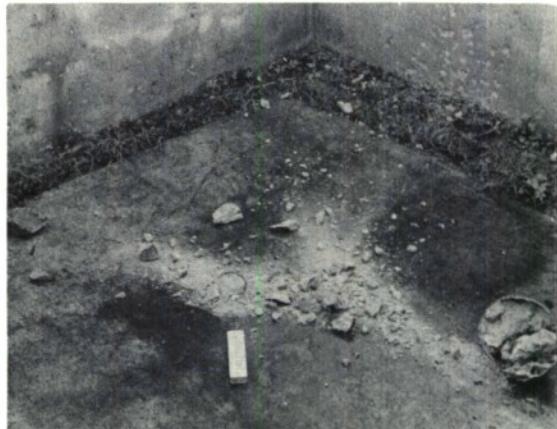


Figure 6 - 59T3256: Damaged Warhead after Impact Onto Armor Plate from a Height of 40 Feet.

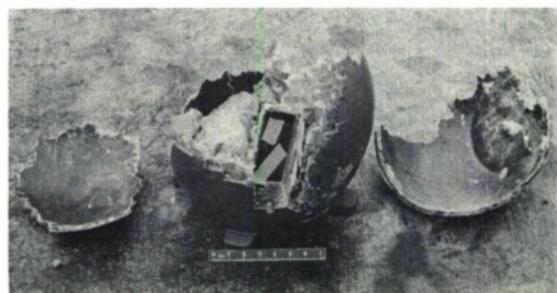


Figure 7 - 59T2358: Damaged Warhead; Broken Safety and Arming Cavity, after Impact Onto Armor Plate from a Height of 40 Feet.

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3.2 (C) Static Detonation Test

3.2.1 General. Two warheads were tested statically. The warheads were assembled with flight skirt and mounted on a pedestal in the center of the test arena. Each warhead was positioned with its longitudinal axis parallel to and located 10 feet above the ground (Figure 8). The position of the safety and arming cavity was directed upward for the first round and rotated 90°, facing the numbered mild steel plates, for the second round. The warheads were positioned 10 feet above the ground to facilitate the blast measurements. Detonation of the warheads was accomplished by means of two blasting caps, electric, type II, wired parallel with the firing line. The caps were placed in the safety and arming cavity on the booster leads and initiated by a 120-volt power source. Figure 9 gives a comprehensive layout of the test and instrument setup.

3.2.2 Fragmentation Phase

3.2.2.1 Procedure. The fragment velocities and spatial distribution of fragments were determined from 4- by 8-foot mild steel plates 3/8 inch thick. The plates were erected vertically on an arc with a radius of 15.19 feet. The plates were arrayed on both sides of the warhead to subtend an angle of 112.5 degrees beginning 45 degrees from the nose end of the warhead (Figure 9). The side of the plates away from the warhead were gridded into 1-foot squares to facilitate the velocity location. The plates were lettered A through H and numbered 1 through 8, H and 8 being at the nose end of the setup (Figure 8). Four high-speed motion-picture cameras, with a framing rate of approximately 7000 feet per second, equipped with high-frequency standards and electronic timing devices, were placed to permit the filming of the detonation of the warhead and of the fragments perforating the steel plates. Four mirrors 4 by 4 inches in size were used to record the image of the warhead detonation for the cameras.

The fragment-mass sample was obtained from four stacks of composition wallboard. Each stack was 6 feet in height and placed beneath the plates, one stack each at 75° and 165° on each side of the warhead. Figure 10 shows the position of the stacks of wallboard.

Figures 11 and 12, show the test site after detonation of the XM5E3 warhead.

After detonation of the warheads fragments were recovered from the composition wallboard to determine the mass distribution.

The impact positions of the fragments striking the mild steel plates were plotted to obtain the spatial distribution.

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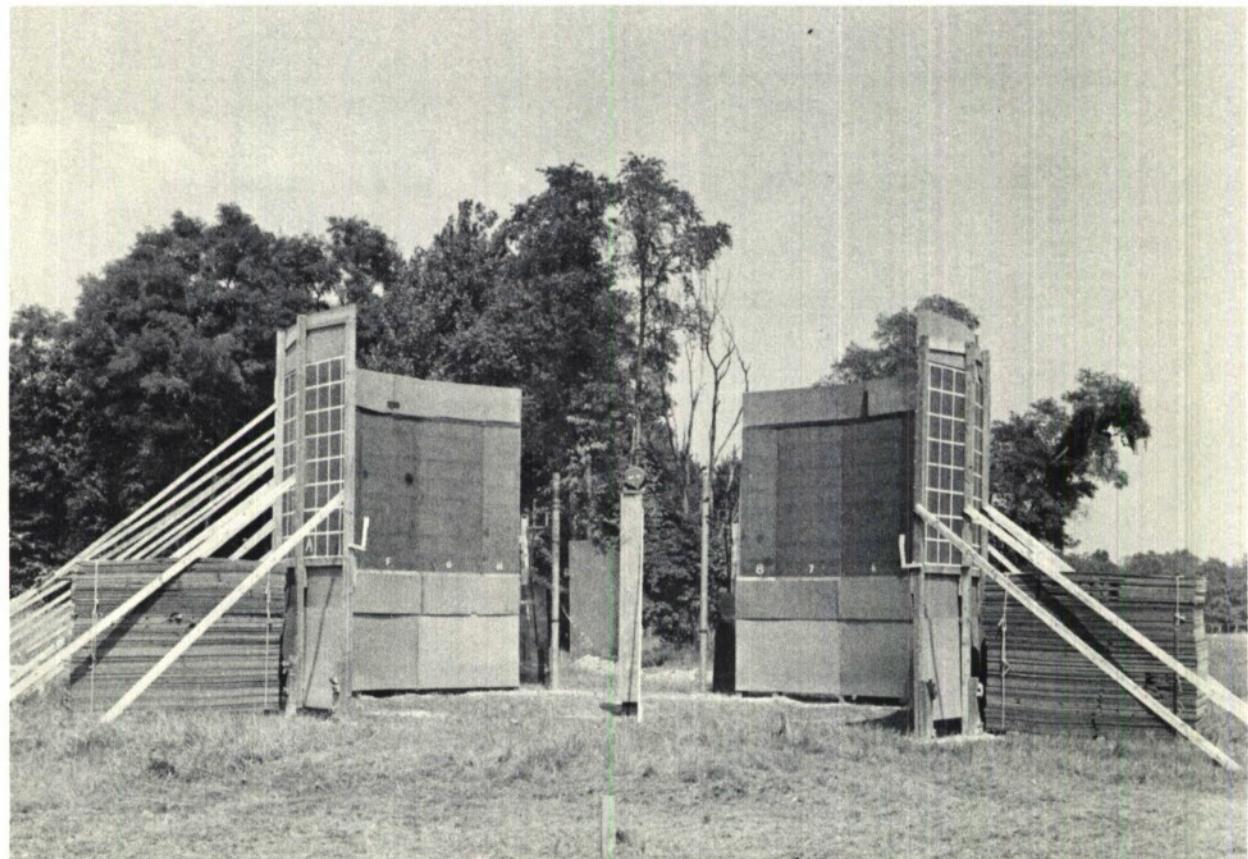
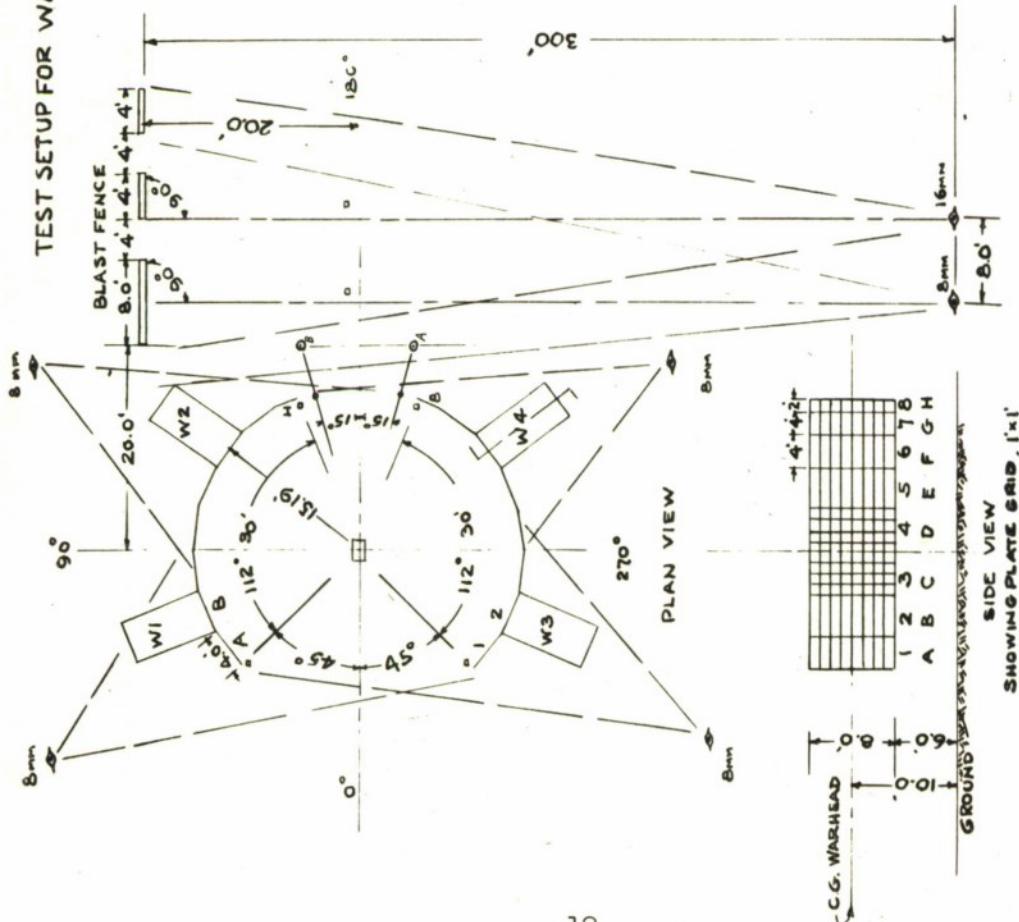


Figure 8 - 59T3203: Test Setup Previous to Firing.

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TEST SETUP FOR WARHEAD XM5E3



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FIGURE 9

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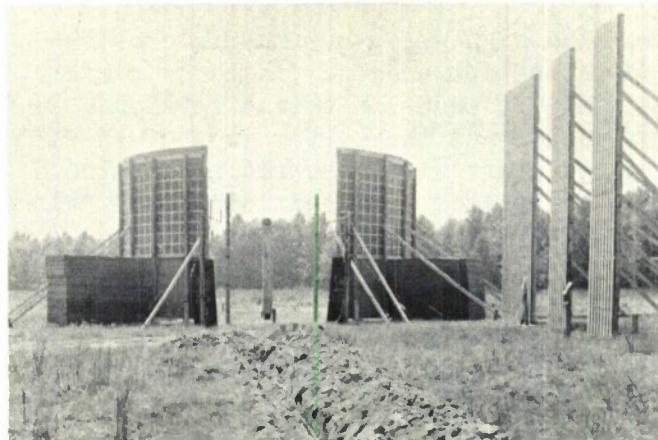


Figure 10 - 59T3204: Test Setup Previous to Firing.

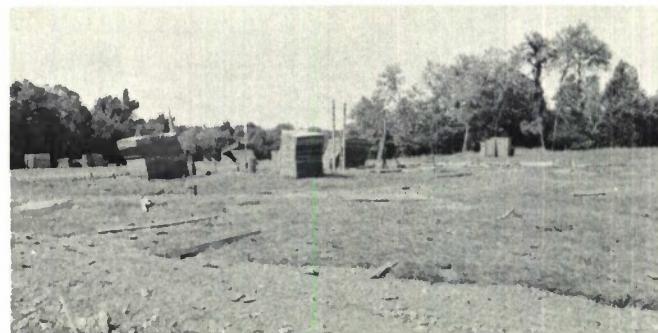


Figure 11 - 59T3594: View of Test Setup after Detonation of Warhead, XM5E3.



Figure 12 - 59T3596: Test Setup after Detonation of Warhead, XM5E3.

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The film from the high-speed motion-picture cameras that photographed the warhead detonation and the fragments perforating the mild steel plates were developed. By means of a time reference on the film, the interval between the detonation and the perforation of the mild steel plates could be found, and this, together with measurements of the distance from the warhead to the mild steel plates, allowed individual velocities to be computed.

3.2.2.2 Results. Table I gives a sample of the mass distribution of the cube fragments of the XM5E3 warhead compared with the XM5E1 warhead.

Table I. Mass Distribution

XM5E1		XM5E3	
<u>Fragment Weight Interval, grains</u>	<u>Per Cent of Total Number Recovered</u>	<u>Fragment Weight Interval, grains</u>	<u>Per Cent of Total Number Recovered</u>
116 to 117	6.3	110 to 111	1.19
117 to 118	3.1	111 to 112	2.39
118 to 119	9.3	112 to 113	3.57
119 to 120	6.3	113 to 114	10.71
120 to 121	12.5	114 to 115	3.57
121 to 122	50.0	115 to 116	10.71
122 to 123	9.4	116 to 117	8.34
123 to 124	3.1	117 to 118	11.90
		118 to 119	7.14
		119 to 120	19.05
		120 to 121	17.86
		121 to 122	3.57

The average weight of the recovered fragments of the XM5E1 was 120.7 grains, whereas for the XM5E3 it was 118.2 grains. Inspection of the fragments of the XM5E1 and the XM5E3 showed that there was only minor deformation.

Individual fragment weights appear in the annex of this report. Figures 13 and 14 show the fragment pattern of the XM5E3 warhead in mild steel plates.

A comparison of the XM5E1 and XM5E3 warheads, as to the number of fragments perforating, the number of velocities recorded, and the average initial velocities (feet per second) of the data obtained from the mild steel plates, is shown in Table II.

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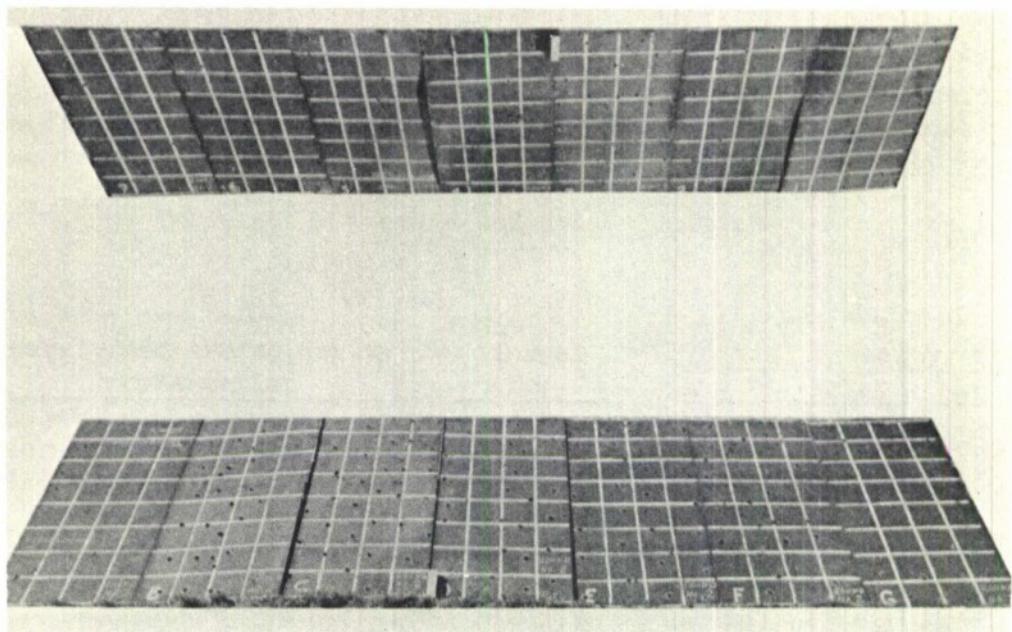


Figure 13 - 59T3726: Fragment Pattern of XM5E3 Warhead in 3/8-Inch Mild Steel Plates at 15 Feet. Round No. 2 (Safety and Arming Cavity Horizontal).

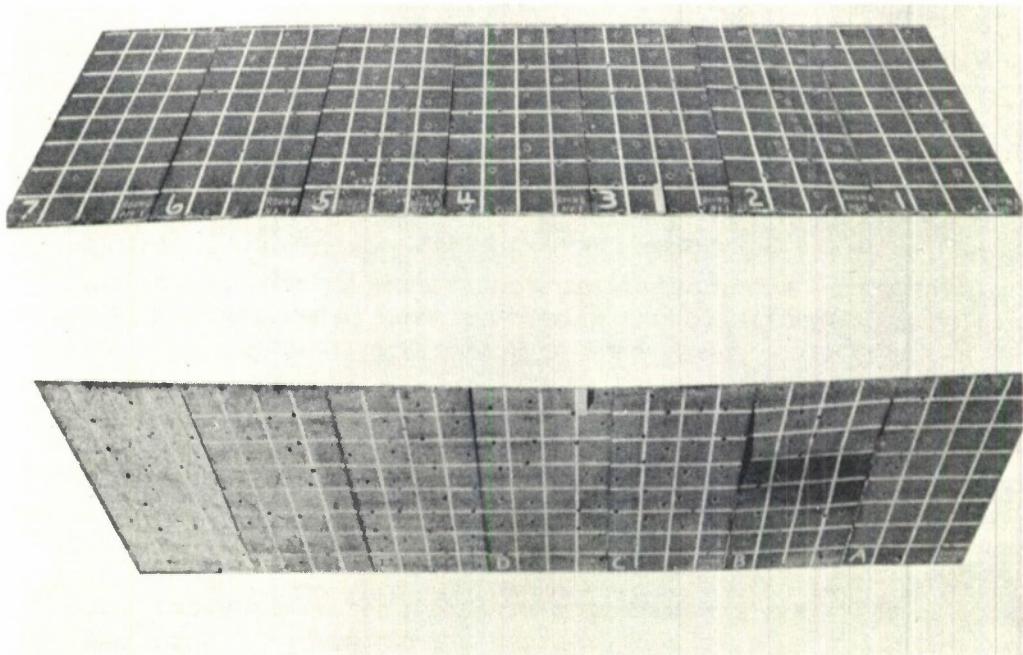


Figure 14 - 59T3727: Fragment Pattern of XM5E3 Warhead in Mild Steel Plates at 15 Feet. Round No. 1 (Safety and Arming Cavity Vertical).

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Table II. Spatial Distribution and Velocity

Target No.	No. Cubes		No. Velocities		Average Velocity, fps		No. Cubes		No. Velocities		Average Velocity, fps	
	XM5E3	XM5E1	XM5E3	XM5E1	XM5E3	XM5E1	XM5E3	XM5E1	XM5E3	XM5E1	XM5E3	XM5E1
(SEA cavity pointing towards the midcenter of the number plates)												
1	5	0	5236	0	5236	0	4	4	2	4	5273	5010
2	27	36	6565	6277	6565	6277	11	24	11	19	5241	5341
3	36	35	6864	6628	6864	6628	22	20	12	17	5957	5595
4	28	32	6985	6516	6985	6516	13	16	10	12	5635	5300
5	28	22	6620	6214	6620	6214	11	13	11	12	4832	4852
6	21	23	5857	5579	5857	5579	15	13	15	11	5334	5270
7	5	1	5199	0	5199	0	13	1	13	1	5666	4255
8	6	0	5923	0	5923	0	1	0	1	0	6043	0
Total	156	149	121	134	6529	6243	90	91	76	76	5380	5089
A	4	0	4	0	5389	0	3	4	2	4	5184	4918
B	32	32	31	28	6240	6293	26	35	26	33	6514	6379
C	34	40	31	34	6773	6756	39	42	34	39	6911	6883
D	26	28	25	26	6673	6623	26	37	26	28	6976	6839
E	24	23	23	22	6262	6218	26	24	23	20	6639	6265
F	15	24	15	23	5674	5702	28	15	25	12	6607	5556
G	9	5	8	5	5872	5547	9	0	9	0	6128	0
H	0	0	0	0	0	0	1	0	0	0	0	0
Total	144	152	137	138	6217	6190	158	157	145	136	6731	6131
Grand Total	300	301	258	272	6379	6214	248	248	221	212	6267	5574

Remark: Results of the XM5E1 were obtained from ARG Firing Record No. B-14172.

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Table III shows the average initial velocity for the preformed fragments for both sets of targets for the XM5E1 and XM5E3 warheads.

Table III. Average Initial Velocities

XM5E3

Round No.	Safety and Arming Cavity Orientation	Target No.	Initial Velocity, fps		
			Avg	Max	Min
1	Up	1 thru 8	6529	7742	4746
		A thru H	6217	7095	4560
2	90°	1 thru 8	5380	8186	4489
		A thru H	6731	7717	4535

XM5E1

1	Up	1 thru 8	6243	7870	4730
		A thru H	6190	7217	4321
2	90°	1 thru 8	5089	7278	4592
		A thru H	6131	7358	4254

Individual fragment velocities and impact distribution are given in Analytical Laboratory Report 59-AL-155, Appendix B.

Spatial distribution plots of the fragments against the mild steel plates are given in Appendix C.

3.2.3 Blast Phase. Two types of instrumentation, one photographic and the other electronic, were used to obtain the blast data.

3.2.3.1 Pressure and Velocity Gages.

Procedure. Crystal pressure transducers were used to record blast pressure as a function of time at two gage locations, identified as A and B (Figure 9).

Calibration of three pressure gages positioned at each location was accomplished by spanning the gages with a pair of velocity gages which recorded arrival times of the shock wave. Velocity of the shock wave was computed from the arrival times and converted to pressures by use of the following equation:

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Rankine-Hugoniot Equation

$$P_s = P_0 \left(\frac{2\gamma}{\gamma+1} \right) \left[\left(\frac{V+K}{V_0} \right)^2 - 1 \right]$$

Where:

 P_s = peak overpressure (psi) P_0 = local atmospheric pressure (psi) γ = specific heats for air (1.4) V = velocity of shock wave (fps) K = correction for effect of wind, taken for each detonation (fps) V_0 = local of speed of sound (fps)

Results. Data on the blast phase of the XM5E3 warhead test, derived from gages, are presented in Table IV.

Table IV. Peak Pressure, in psi, Derived from Pressure and Velocity Gages

<u>Gage Location</u>	<u>Gage and Position on Gage Stand</u>	<u>Detonation 1</u>	<u>Detonation 2</u>
A	Velocity	74.5	92.3
	Pressure (top)	7.2	18.8
	Pressure (center)	27.3	22.0
	Pressure (bottom)	29.2	20.5
B	Velocity	58.2	110.7
	Pressure (top)	20.2	19.5
	Pressure (center)	38.3	19.2
	Pressure (bottom)	34.1	18.6

The pressure traces for all pressure gages at position A were erratic and oscillatory. It is quite probable that this position was engulfed by flame or heat at about the time the shock wave arrived. The crystals used in these pressure transducers react adversely to heat. Except for the values obtained from the top pressure gages for detonation 1, there appears to be good agreement among pressure gages, by position.

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The pressures computed from velocity gages are not valid. As discussed above, the shock front did not traverse the pair of velocity pick-up gages normally (i.e., the shock wave did not move as a plane normal to the line joining the gages). The difference between times of arrival at the two gages did not correspond to the travel distance of the shock front equal to that distance between gages. Unfortunately the actual travel could not be computed from the Fastax film because the shock front in the vicinity of the velocity gages was obscured by the jet.

3.2.3.2 Photographic Fence Method.

Procedure. The fence technique was included to supplement the usual instrumentation (pressure and velocity gages) because erratic pressure-time histories had been obtained on previous testing of this type warhead.

A fence consisting of equally spaced vertical divisions (called 'poles') is photographed by Fastax cameras during the passing of the shock front. Light waves passing from undisturbed air to the turbulent region immediately behind the front undergo an abrupt change in direction. This phenomenon appears on the film as distortion or deletion of successive fence poles as the front moves away from the point of detonation.

Three fences, one 8 feet and two 4 feet wide and subdivided into 3-inch alternating black and white vertical stripes, were placed as shown in Figures 10 and 15. Two 16-mm Fastax cameras, one of which was half-framed, were employed. The line of sight of the half-framed camera was perpendicular to the midpoint of the 8-foot fence, while the line of sight from the other camera was perpendicular to the edge (nearest the warhead) of the first 4-foot fence.

Results. Examination of the film records showed that a jet probably consisting of extremely hot gases and burning particles of explosive was emitted in the direction of the gage stands immediately after detonation. The center of this moving mass was located half way up the fence, 10 feet above the ground, at the same height of the gage clusters (Figure 16). The brightness of the jet over-exposed the portions of the film immediately bordering the jet front, thereby preventing accurate reduction of its velocity as a function of fence distance. However, it was possible to estimate velocity of the jet from the first few frames in which the front silhouetted the beginning of the 8-foot fence. This velocity was between 2500 and 3000 fps. The jet stream slowed down considerably before traveling the 12-foot distance to the beginning of the first 4-foot fence.

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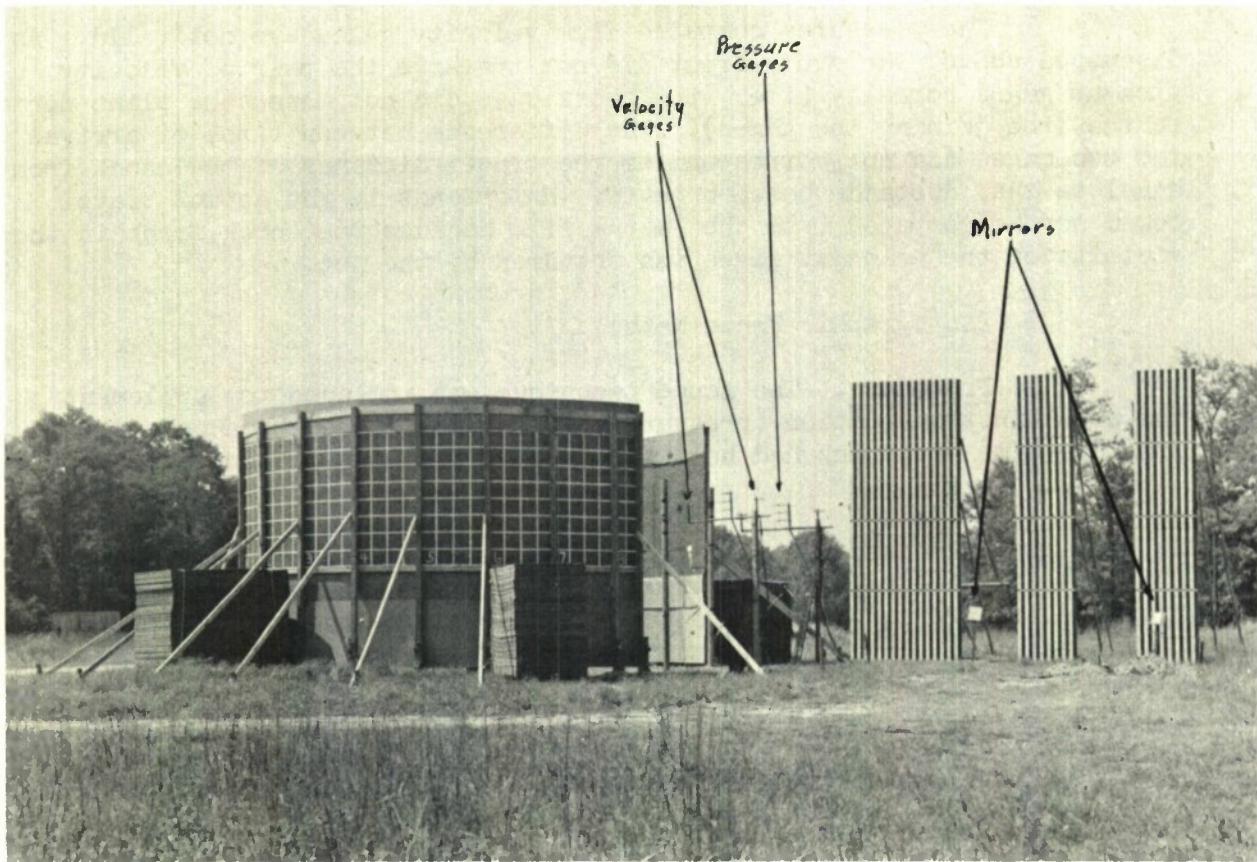


Figure 15 - 59T3205 (U): Blast Fence and Plate Area.

Formation of a shock front was not evident on the film until the jet front had traversed the 8-foot fence. At this time, a shock wave began forming in the top and bottom quarter of the fence at approximately the beginning of the fence. (The 20-foot height of the fence was divided, vertically, into four sections by horizontal cross bars.) In other words, the formation of a shock wave trailed the jet front by 6 to 8 feet, but as the front moved away from the detonation, shock wave formation became clearer.

Initially, the slope of the wave was quite sharp, making a 30° to 40° angle with the horizontal. As the wave moved laterally away from the beginning of the 8-foot fence, this angle increased until, at some greater distance, the shock wave would appear perpendicular to the horizontal. This results because the detonation of the warhead emits, for all practical purposes, a spherical shock front. As the diameter of the sphere increases, the curvature of the arc which is seen against the targets decreases.

Photographs of the second detonation (Figure 16) show the sequence of events mentioned above. A second shock front, opposite in orientation to the first, is also visible. This is the reflected wave (initial wave reflected off the ground) which eventually overtakes and joins the initial wave some distance beyond the fences.

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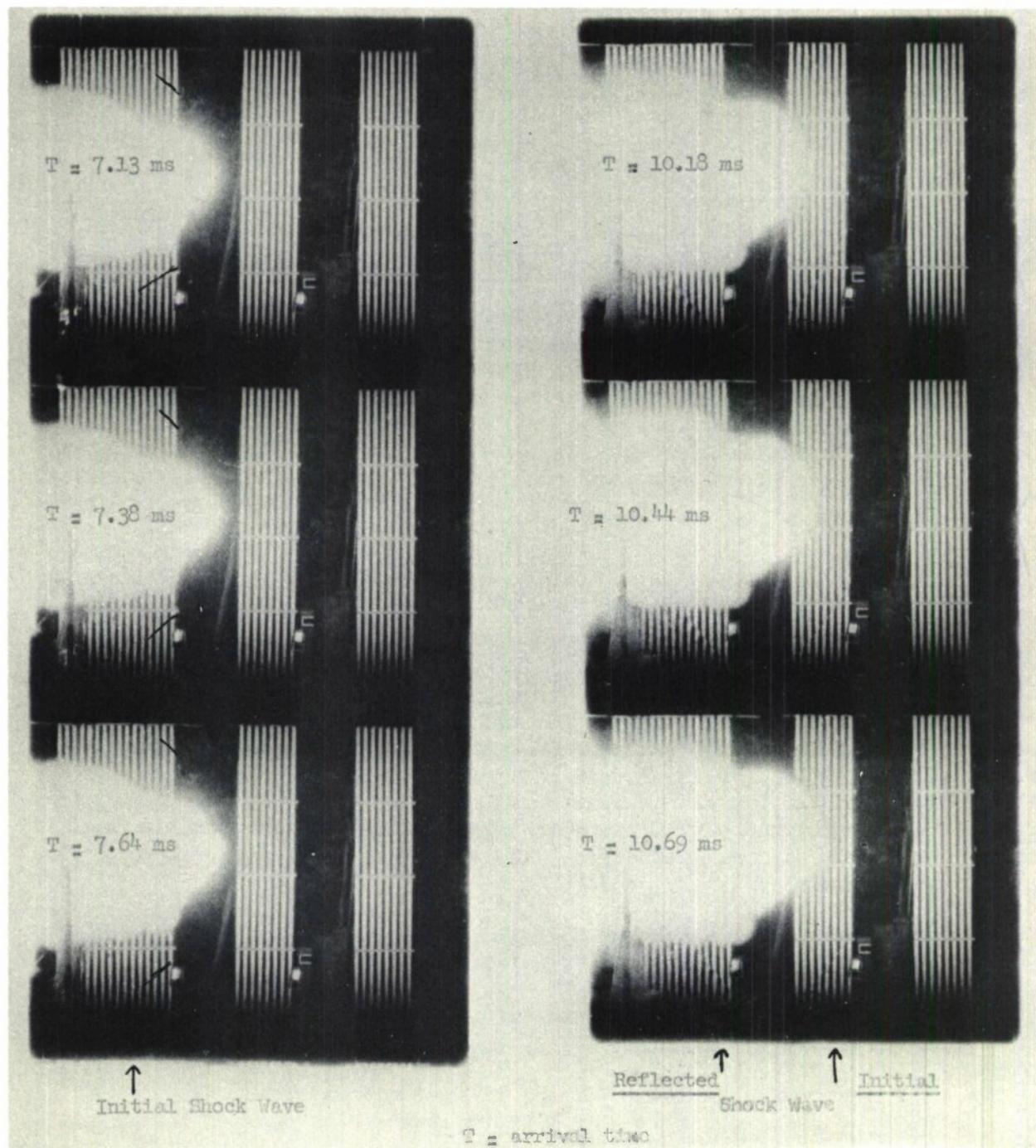


Figure 16: Photograph of Shock Wave for XM5E3 Warhead Detonation.

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Data on the fence phase of the XM5E3 warhead test are presented in Table V.

Table V. Pressure, psi, Derived by the Fence Technique

Detonation 1		Detonation 2	
Time, ms	Pressure, psi 16-mm	Time, ms	Pressure, psi 8-mm 16-mm
		6.46	45.0
		6.93	32.3
5.43	35.0	7.39	32.3
5.89	41.3	7.75	27.6
6.35	35.9		9.80
6.81	28.9		10.31
			10.82
			11.33
			14.64
			15.15
			15.66
			16.16
			16.67

Pressure data from the fence technique are very limited for detonation No. 1. Lack of sunlight because of cloudy and overcast sky at the time of this detonation reduced the number of observations available from the Fastax film. No shock wave refraction was discernible for the 8-mm film and only a few values were obtained at the beginning of the fence from the 16-mm film. Observations were available from both the 8-mm and 16-mm film for the second detonation. The agreement of pressure values between these cameras is very good.

Blast data on the XM5 warhead given below were obtained from Technical Note No. 1170, Ballistic Research Laboratory, APG.

From air shock velocities inferred from measurements of the shock arrival times, the calculated side-on peak excess pressure are as follows:

Peak Pressure, psi

45.0
38.5
43.5
44.3

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On the average, the XM5 warhead produced a free-air peak blast pressure of about 42.3 psi at a distance of 20 feet. Based on the free air measurements, the air blast from the warhead is equivalent to approximately 88 pounds of bare 50/50 pentolite.

4. (C) CONCLUSIONS

Mass distribution of the cube fragments of the XM5E3 warhead are comparable with those of the XM5E1.

The fragments of the XM5E3 warhead had an initial velocity of 6457 feet per second; this is an increase of 315 feet per second over the XM5E1 warhead.

By the incorporation of the safety and arming liner and booster extension into a one-piece design, the initial velocities of the fragments from this section of the XM5E3 warhead showed an increase of 500 feet per second over the XM5E1 warhead.

The readings of the electronic instruments were inadequate for the XM5E3 warhead; therefore it was deemed inadvisable to use them for comparison of blast data. The photographic fence technique, which is relatively new, indicates that blast pressures at 20 feet from the XM5E3 warhead are 30 psi.

The XM5E3 warhead did not detonate when dropped onto armor plate from a height of 40 feet, but was rendered unserviceable.

The production engineering changes incorporated in the XM5E3 warhead did not detrimentally affect the established functional or safety requirements.

5. (C) RECOMMENDATIONS

It is recommended that the incorporated production engineering changes be adopted.

In future detonations of the XM5 warhead, electronic measurements should be made at a distance of 25 feet or greater.

The photographic fence technique should be used in addition to electronic gages to obtain blast data.

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SUBMITTED:

Edwin L. Seiple

EDWIN L. SEIPLE
Technical Engineer

REVIEWED:

V. L. Grafton

V. L. GRAFTON
Chief, Terminal Effects and
Special Projects Branch

Claude E. Brown

C. E. BROWN
Chief, Infantry and Aircraft
Weapons Division

APPROVED:

H. A. Noble

H. A. NOBLE
Assistant Deputy Director
for Engineering Testing
Development and Proof Services

REFERENCES (U)

1. APG, D&PS, Firing Record No. B-14268.
2. APG, D&PS, Firing Record No. B-14172.
3. APG, D&PS, Firing Record No. B-14142.
4. APG, BRL Technical Note No. 1170.

APPENDICES

	<u>PAGE NO.</u>
A, CORRESPONDENCE	A-1
B, ANALYTICAL LABORATORY REPORT NO. 59-AL-155	B-1
C, SPATIAL DISTRIBUTION PLOTS	C-1
D, ANALYTICAL LABORATORY REPORT NO. 59-AL-153	D-1
E, DISTRIBUTION	E-1

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ORDNANCE CORPS
PICATINNY ARSENAL
DOVER, NEW JERSEY

APPENDIX A

Correspondence

Mr. RCrater/evr/2252

MAY - 8 '59 - 9 AM

IN REPLY
REFER TO:
INDUSTRIAL ENGINEERING DIVISION
ORDBB-DC4

SUBJECT: Test Program Request No. D-77
Static Firing and Drop Test of
Production Engineered XM5E3 Warhead (U)

2002-65-2007

TO: Commanding General
Aberdeen Proving Ground
Aberdeen, Maryland
ATTENTION: Development & Proof Services

1. The inclosed Test Program Request covers tests required in evaluation of changes incorporated into the XM5E2 Warhead as a result of a production engineering study. The sample warheads and the missile warhead compartment required for the tests will be shipped to your Proving Ground approximately 1 August 1959.
2. The items to be tested are for use in the Hawk Missile System which has been assigned No. 25 Cue Cap priority by the Department of Defense. It is requested that the work desired be scheduled accordingly.
3. Funds required will be furnished your facility upon receipt of cost estimate.

FOR THE COMMANDER:

H. D. Rutkovsky
H. D. RUTKOVSKY
Assistant

1 Incl

1. Test Program Request
No. D-77 (in dupes)

CC
OAC, ORDLY-ARBR (w/Incl)

Action Dots
Storm Sys: 8-13
Conanc
Compt.

17669

A-1
Regraded Unclassified When Separated From
Incl

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Mr. RCrater/evr/2252
Picatinny Arsenal, Dover, N. J.
5 May 1959
Test Program Request No. D-77

MAY - 8 59 - 9 AM

1. (U) Material for Test

Three each Warhead, Guided Missile, XM5E3

2. (U) Project Authority

PESD 70304121-13-40010-08-2-311
PESD 80304120.1-13-90019-01-2

3. (U) Arsenal Expenditure Order No.

Work Order 6981-38

4. (U) Object of Product Engineering Investigation

To facilitate production and reduce manufacturing costs and lead time.

5. (U) Historical Sketch

As a result of a production engineering study conducted by the Aerojet General Corporation, several changes have been proposed to the original XM5E2 Warhead design which are intended to considerably reduce the cost of fabricating the inert parts. Based on an engineering evaluation of the proposed changes, it is considered that their incorporation will not detrimentally affect the established functional or safety requirements. However, prior to final acceptance, actual testing of sample warheads, with these changes incorporated, is desired. The tests covered by this Test Program Request are for this purpose.

Static firing and drop tests involving the XM5E2 Warhead were conducted at Aberdeen Proving Ground during original development of this item.

6. (C) Description in Detail of Improvements Made Since Last Proving Ground Test -

- a. Outer Body - epoxy resin coating over fragments substituted for plastic laminate Outer Body.

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TEST PROGRAM REQUEST NO. D-77 (Cont.)

- b. Inner Body - redesigned: fabricated in halves by compression molding process in which matched - metal molds incorporate After Plate, Inner Body, Forward Plate, Locator Well, Locator Bushing, Forward Reinforcement Ring, After Reinforcement Ring and Helix Fragment Support into an integral unit. Plastic laminate material replaced by glass - fiber - reinforced polyester molding compound.
- c. Fore Plate - glass fiber reinforced polyester molding compound substituted for aluminum.
- d. S and A Liner and Booster Extension - These two components incorporated into a one piece design.

7. (U) Local Tests

None

8. (U) Object of Test

- a. To determine whether the XM5E3 Warhead, incorporating production engineering changes, will withstand a 40 ft drop onto armor plate without detonation.
- b. To determine whether fragment velocity, fragment distribution, or blast effects of the XM5E2 Warhead has been detrimentally affected as a result of the production engineering changes.

9. (C) Precautions in Handling and Testing -

- a. Each Warhead is loaded with approximately 73 lbs of H-6 explosive. A small quantity of Micro-Cel-E (a synthetic calcium silicate), 0.3% by weight, is incorporated in the explosive filler to prevent exudation. The Booster Assembly contains approximately 862 grains of RDX.
- b. No extraordinary handling precautions are required, however, the usual precautions in handling and testing loaded warheads should be observed.

10. (C) Recommended Test Program

- a. Drop test - One warhead will be dropped onto armor plate from a height of 40 ft. Point of impact will be directly upon the Safety and Arming Liner cavity. Warhead will contain complete Booster Assembly. Observe for evidence of detonation and/or damage to the warhead components. After completion of test, warhead shall be destroyed at the test site.

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TEST PROGRAM REQUEST NO. D-77 (Cont.)

- b. Static Firing - Two warheads shall be statically fired to obtain fragment velocities, fragment distribution and blast effects. Peak pressure and impulse at a distance of 20 feet from the warhead shall be obtained.

Tests will be conducted with warheads assembled in missile warhead compartments. These assemblies will be positioned on a scaffold in a horizontal position (a) one with the Safety and Arming cavity pointing straight up (vertical) and (b) the other the same as (a) except the Warhead Safety and Arming Cavity will be horizontal. Warhead initiation to be accomplished through use of an M36 electric detonator.

- c. The following is also desired:

- (1) Photographs of the warheads and test arena as set up for the tests.
- (2) Photographs of damage to warhead subjected to the drop test.
- (3) Photographs of representative target damage after the static firing test.
- (4) A formal test report.

11. (U) References

- a. Aerojet Drawing 1-056386, 9-26-58
- b. Aerojet Drawing 1-056387, 9-26-58
- c. Aerojet Drawing 1-056388, 9-26-58
- d. Aerojet Drawing 1-056389, 9-25-58
- e. Aerojet Drawing 1-056390, 9-26-58
- f. Aerojet Drawing 1-056391, 9-26-58
- g. Aberdeen Proving Ground Firing Record No. B-14019
- h. Aberdeen Proving Ground Firing Record No. B-14114
- i. Aberdeen Proving Ground Firing Record No. B-14142

12. (U) Coordination

- a. Army Rocket and Guided Missile Agency, CRDXR-IH
- b. Ordnance Ammunition Command, CRDLY-ARER
- c. Aberdeen Proving Ground
- d. Picatinny Arsenal

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TEST PROGRAM REQUEST NO. D-77 (Cont.)

13. (U) Report Distribution

- a. Test Report Security Classification - Confidential
- b. 4 Copies - Picatinny Arsenal

2 copies QRDBB-DC4, ATTN: Mr. R. Crater
1 copy QRDBB-TH8
1 copy QRDBB-K

6 Incls

- 1. Aerojet Dwg 1-056386, 9-26-58 (Confidential)
- 2. " " 1-056387, " " "
- 3. " " 1-056388, " " "
- 4. " " 1-056389, 9-25-58
- 5. " " 1-056390, 9-26-58
- 6. " " 1-056391 " " "

R. Crater
R. Crater
Assistant

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C O P Y/tsp

RAYTHEON MANUFACTURING COMPANY

MISSILE SYSTEMS DIVISION

MDG:bc:7202:2975

22 June 1959

Industrial Engineering Division
Picatinny Arsenal
Dover, New Jersey

Attention: Mr. R. Crater, ORDBB-DC4

Subject: Support Assemblies

Enclosure: Eight (8) Support Assemblies

Gentlemen:

Enclosed are eight (8) Support Assemblies for mounting the XM5E3 Warhead in the scrap warhead shells forthcoming from Aerojet-Azusa for the tests at Aberdeen Proving Ground.

Very truly yours,

RAYTHEON COMPANY

/s/ M. D. Gidez
/t/ M. D. GIDEZ
Project Engineer

1 cy ltr w/l set encs

C O P Y/tsp

RAYTHEON MANUFACTURING COMPANY

MISSILE SYSTEMS DIVISION

ANDOVER, MASSACHUSETTS . ANDOVER 3400

MDG:emt:7202:3030

20 July 1959

Picatinny Arsenal
Dover, New Jersey

Attention: R. Crater, Industrial Engineering Division
ORDBB-DC4

Subject: Warhead Support Pins

Enclosure: Two Warhead Support Pins

Dear Sir:

Enclosed are two Warhead Support Pins that you requested for the static tests of the Aerojet Warhead.

Very truly yours,

RAYTHEON COMPANY

/s/ M. D. Gidez
/t/ M. D. GIDEZ
Project Engineer

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C O P Y/tsp

APPENDIX B

Analytical Laboratory Report 59-AL-155

19 November 1959

Title: Results of Fragmentation Test of Warhead, XM5E3

Prepared for: Bomb and Fragmentation Br, Infantry and Aircraft Weapons Div

Project No.: PA-I/58/D77

INTRODUCTION

(U) A test was conducted to obtain fragment velocity and blast data for the XM5E3 Warhead. Two rounds were fired for this purpose. This report presents the data obtained concerning the fragment velocities and the distribution of those velocities.

TEST PROCEDURE

(U) To determine the velocities of the fragments, the warheads were detonated at the center of a test arena consisting of 4' x 8' upright targets of 3/8" mild steel plate arranged in two symmetrical arcs of 112.5° on opposite sides of the warhead, see Incl 1, Fig. 1. The distance from the center of the test arena to the targets was 15.19 feet. The axis of the warhead was horizontal and symmetrically separated the test arena (nose end at 0°), the target plates started at 45° and continued to 157.5°. The targets on one side were numbered 1 through 8, and on the other side were lettered A through H with plates 1 and A at the nose end of the arcs. Also, the last two targets (A and H) were only two feet wide, compared to 4 feet for the other targets. To aid in locating fragment impacts for plotting and for film reading, the targets were painted with a 1' x 1' grid.

(U) Four camera stations were used; two for each arc, with each station having two cameras covering the same targets as a precaution against loss of data because of camera failure. The detonation of the warhead was recorded on the film by means of mirrors placed in the field of view of each camera. The impacts of the fragments on the plates were recorded as flashes of light on the film which had a millisecond time base for the determination of fragment flight times.

(C) Most of the velocities obtained were for the preformed fragments encasing the warhead, since only these fragments had sufficient mass and velocity to perforate the 3/8" plates. The orientation of the two rounds was different. The first round was mounted with the axis horizontal and the S&A (Safety and Arming) cavity directed upward. The S&A cavity is a tapered opening in the side of the warhead into which the firing device is inserted. The second round was mounted with the S&A cavity on the side and directed towards the numbered targets (1 thru 8).

DATA REDUCTION

(U) The travel distance of the fragments was determined in such a manner as to be accurate within 1%. From the individual fragment flight times and these

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59-AL-155

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distances, the photographic velocities were then obtained. While most of the perforations in the targets were produced by preformed fragments, a few resulted from other miscellaneous fragments. A check was made against plot sheets of the perforated targets to separate the preformed and miscellaneous fragment velocities.

(c) The initial velocities (V_0) were then computed according to procedures given in Report No. DPS/APG Misc/306; DPS/I&IT/5. The mass-area relationship and drag were determined for the preformed fragments, but the same values were used in computing the initial velocities for all fragments, since no data were available on the miscellaneous fragments perforating the plates. The preformed fragments had dimensions of $1/2" \times 1/2" \times 1/4"$ with a nominal weight of 120 grains. Therefore, the initial velocities given in Incl 2 identified as "other perforations" may be 5-10% lower than the actual values.

RESULTS

(U) Included in the tabulated data for each round in Incl 2 are the initial velocity for each fragment and the location of the $1' \times 1'$ square in which the perforation occurred. The locations of the impacts are given first by target, 1-8 or A-H's, then by vertical row, 1-4, corresponding to each one foot wide interval for the targets; and finally by square, A-H, identifying the one foot interval from the top of the plates. Average velocities for the preformed fragments were determined for each vertical row or one foot interval around the warhead. Plots of the average velocities are shown in Fig. 2, Incl 1. It is to be noted that in the tabulated data of Incl 2, the row numbers read from left to right for Target Nos. 1-8, but from right to left for Target Nos. A-H, i.e., Row No. 1 for all targets is toward the nose end or 0° orientation.

(C) The following table shows the average initial velocity for the preformed fragments for both sets of targets for the two warheads.

Rd No.	S&A Cavity Orientation	Target No.	Initial Velocity, fps					No. of Preformed Vel Cons.
			Ave	Row Ave*	Individual Value	Max	Min	
1	Vertical (up)	1-8	6556	7161	4984	7742	4746	149
		A-H	6335	6822	4763	7095	4560	137

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Rd No.	S&A Cavity Orientation	Target No.	Initial Velocity, fps				No. of Preformed Vel Cons.	
			Ave	Row Ave*	Individual Value	Max	Min	
2	Horizontal (Towards Targets 1-8)	1-8	5450	6858	4646	8186	4489	76
		A-H	6683	7041	5015	7717	4535	146

* A total of thirty rows per target arc; four for each of seven targets and two for one target. The angular width of each row is 3.75°.

SUBMITTED:

Henry L. Barnhart

Henry L. Barnhart

Mathematician

REVIEWED:

Wilbert E. Cantey

Wilbert E. Cantey

Chief, Ballistics Section

APPROVED:

A. E. Karp

A. E. KARP

Chief, Analytical Laboratory

Inclosures

Incl 1 - Fig. 1 Sketch of test setup

Fig. 2 Plot of initial velocity vs angle θ

Incl 2 - Tabulated Data

Engineering Laboratories

Supporting Services

Development and Proof Services

Aberdeen Proving Ground, Maryland

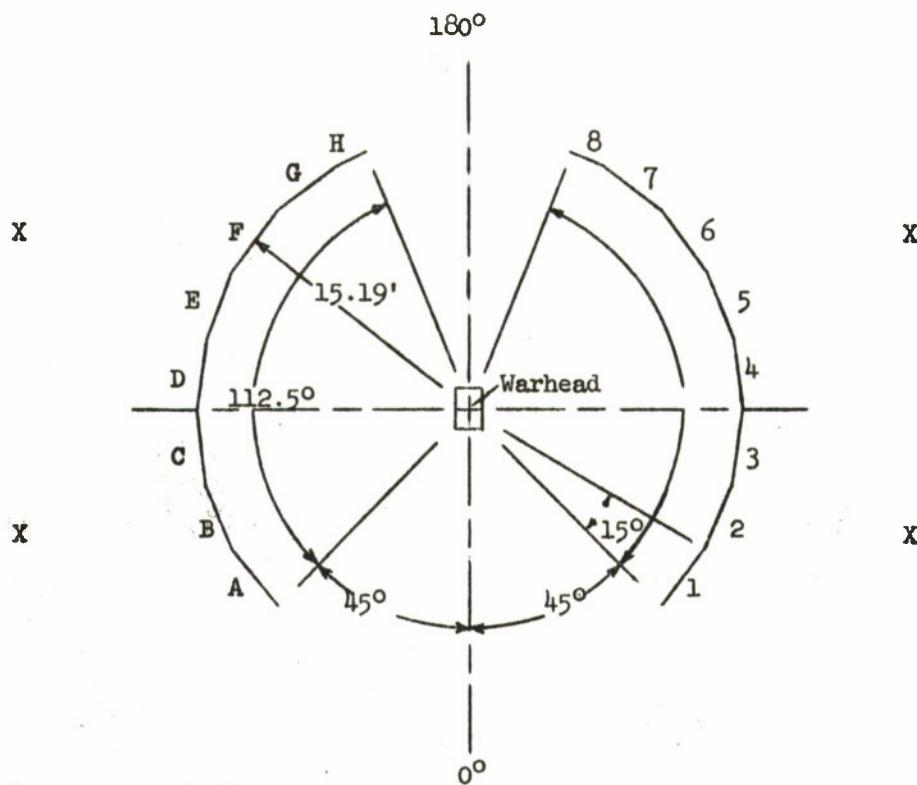
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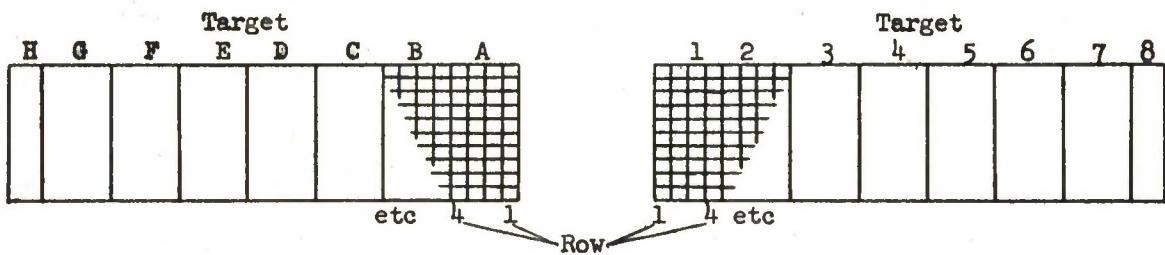
59-AL-155

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Sketch of Test Setup



X indicates camera station



Note: The target plates were mounted with the bottom edge of the plates 6 ft above the ground with the warhead mounted in the center 10 ft above the ground.

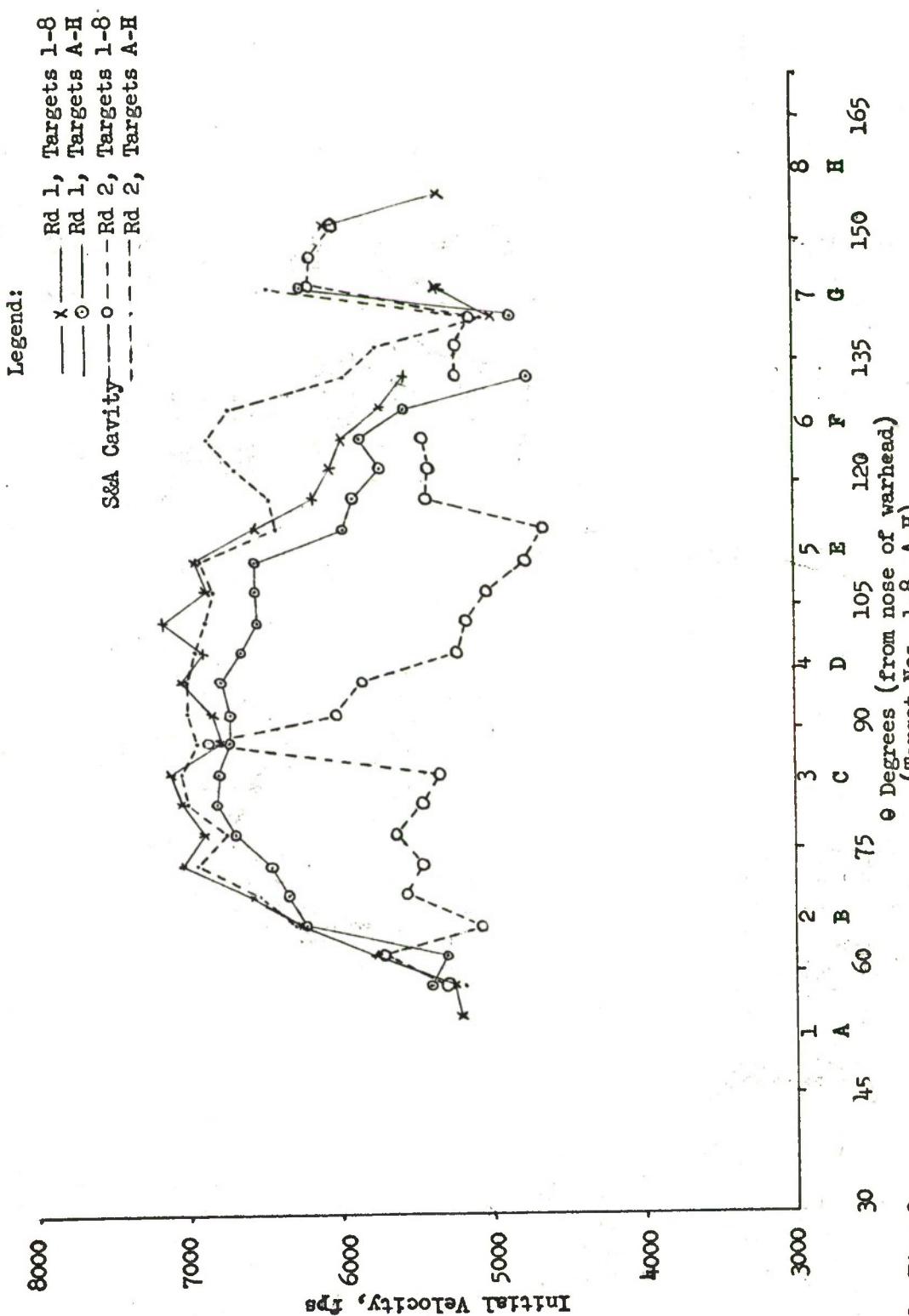
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Nov 59 HLB

Incl 1, Fig. 1

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Initial Velocity vs Angle θ
XM5E3 Warhead



Incl 1, Fig. 2

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Fragment Velocities and Impact Distribution Data

Round Number 1
Date of Firing: 29 Sept 1959

<u>Row</u>	<u>Square</u>	<u>Frag. travel Distance, ft</u>	<u>Velocity, F/S Individual</u>	<u>Velocity, F/S Ave</u>	<u>No. of Preformed Frags. Cons.</u>	<u>% Error</u>
<u>Target 1</u>						
3	G	14.89	5146	5200	2	± 6
	H	15.19	5254			
4	D	14.59	5878	5261	3	± 6
	E	14.59	5039			
	F	14.59	4865			
<u>Target 2</u>						
1	G	14.89	5763	5763	1	± 6
2	A	15.19	6129	6272	7	± 7
	B	14.89	6264			
	E	14.59	6718			
	F	14.59	6718			
	F	14.59	5643			
	G	14.89	6549			
	H	15.19	5884			
3	A	14.89	6549	6570	10	± 7
	B	14.89	6860			
	B	14.59	6412			
	C	14.59	6718			
	D	14.59	6718			
	D	14.59	6718			
	E	14.59	6718			
	E	14.59	5426			
	G	14.59	6718			
	H	14.89	6860			
4	A	15.19	7005	7038	6	± 7
	B	14.89	6860			
	D	14.59	7053			
	E	14.59	7053			
	F	14.59	7053			
	G	14.89	7204			

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Incl 2

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Fragment Velocities and Impact Distribution Data

Round Number 1
Date of Firing: 29 Sept 1959

<u>Row</u>	<u>Square</u>	<u>Frag. travel Distance, ft</u>	<u>Velocity, F/S Individual</u>	<u>Ave</u>	<u>No. of Preformed Frags. Cons.</u>	<u>% Error</u>
<u>Target 3</u>						
1	A	14.89	7204	6897	12	+ 7
	B	14.59	7053			
	C	14.59	7053			
	D	14.59	7053			
	D	14.59	7053			
	E	14.59	7053			
	E	14.59	5126			
	F	14.59	7053			
	G	14.89	7204			
	G	14.59	7053			
	H	15.19	7005			
	H	14.89	6549			
2	A	15.19	7005	7033	7	+ 7
	B	14.89	7204			
	C	14.59	7053			
	E	14.59	7053			
	F	14.59	7053			
	G	14.89	6860			
	H	15.19	7005			
3	A	15.19	7005	7113	11	+ 7
	B	14.89	7204			
	C	14.59	7053			
	C	14.59	7053			
	D	14.59	7053			
	F	14.59	7053			
	F	14.59	7053			
	G	14.89	7204			
	G	14.89	7204			
	H	15.19	7354			
	H	15.19	7005			
4	A	15.19	7005	6777	6	+ 7
	A	14.89	6549			
	B	14.89	7204			
	D	14.59	7053			
	D	14.59	6718			
	E	14.59	6133			

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6

Fragment Velocities and Impact Distribution Data

Round Number 1
Date of Firing: 29 Sept 1959

<u>Row</u>	<u>Square</u>	<u>Frag. travel Distance, ft</u>	<u>Velocity, F/S Individual</u>	<u>Ave</u>	<u>No. of Preformed Frags. Cons.</u>	<u>% Error</u>
<u>Target 4</u>						
1	A	15.19	7005	6827	9	+7
	B	14.89	6860			
	C	14.59	7053			
	E	14.59	6718			
	E	14.59	6133			
	F	14.59	7053			
	G	14.89	7204			
	G	14.59	6412			
	H	15.19	7005			
2	A	15.19	7005	7033	7	+7
	B	14.89	6860			
	C	14.59	7053			
	D	14.59	7053			
	F	14.59	7053			
	G	14.89	7204			
	H	15.19	7005			
3	A	14.89	6860	6989	6	+7
	B	14.59	7053			
	D	14.59	7053			
	E	14.59	7053			
	F	14.59	7053			
	G	14.89	6860			
4	A	15.19	7742	7161	6	+7
	B	14.89	6860			
	C	14.59	7053			
	D	14.59	7053			
	F	14.59	7053			
	G	14.89	7204			

Incl 2

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59-AL-155

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Fragment Velocities and Impact Distribution Data

Round Number 1

Date of Firing: 29 Sept 1959

<u>Row</u>	<u>Square</u>	<u>Frag. travel Distance, ft</u>	<u>Velocity, F/S Individual</u>	<u>Ave</u>	<u>No. of Preformed Frags. Cons.</u>	<u>% Error</u>
<u>Target 5</u>						
1	A	15.19	6686	6873	7	+ 7
	B	14.89	6860			
	C	14.59	7053			
	D	14.59	7053			
	F	14.59	7053			
	G	14.89	6860			
	H	14.89	6549			
2	B	14.89	6860	6937	8	+ 7
	C	14.59	7424			
	C	14.59	6718			
	D	14.59	7424			
	D	14.59	7053			
	E	14.59	6412			
	G	14.59	7053			
	H	14.89	6549			
	F	14.59	6718 *			
3	B	14.89	6264	6544	6	+ 7
	C	14.59	6412			
	D	14.59	6412			
	F	14.59	6412			
	F	14.59	6412			
	H	15.19	7354			
4	B	14.89	6264	6159	5	+ 6
	C	14.59	6133			
	D	14.59	6133			
	E	14.59	6133			
	G	14.59	6133			
<u>Target 6</u>						
1	A	14.89	5902	6061	6	+ 7
	B	14.89	6170			
	D	14.59	6041			
	E	14.59	6041			
	F	14.59	6041			
	F	14.89	6170			

* Other perforation than preformed fragment, not considered in average

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Fragment Velocities and Impact Distribution Data

Round Number 1

Date of Firing: 29 Sept 1959

<u>Row</u>	<u>Square</u>	<u>Frag. travel Distance, ft</u>	<u>Velocity, F/S</u>		<u>No. of Preformed Frags. Cons.</u>	<u>% Error</u>
			<u>Individual</u>	<u>Ave</u>		

Target 6 (Cont')

2	B	14.89	5902	5986	5	£ 7
	E	14.59	5779			
	F	14.59	5779			
	G	14.89	6170			
	H	15.19	6299			
3	A	15.19	4764	5707	7	£ 7
	B	14.89	5902			
	D	14.59	5779			
	D	14.59	5779			
	D	14.59	5779			
	E	14.59	5779			
	G	14.89	6170			
4	E	14.59	5779	5548	2	£ 6
	F	14.59	5316			

Target 7

2	C	14.59	4746	4984	2	£ 6
	G	14.89	5221			
3	A	14.89	6170	5343	3	£ 7
	D	14.59	4746			
	F	14.59	5112			
4	E	14.59	4027 *		0	£ 5

Target 8

1	A	14.89	6170	6073	4	£ 7
	B	14.59	6041			
	D	14.59	6041			
	D	14.59	6041			
2	E	14.59	5316	5316	1	£ 6

* Other perforation than preformed fragment, not considered in average.

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Fragment Velocities and Impact Distribution Data

Round Number 1

Date of Firing: 29 Sept 1959

<u>Row</u>	<u>Square</u>	<u>Frag. Travel Distance, ft</u>	<u>Velocity, F/S Individual</u>	<u>Ave</u>	<u>No. of Preformed Frags. Cons.</u>	<u>% Error</u>
<u>Target A</u>						
4	A	14.89	5197	5398	4	+7
	C	14.59	5088			
	D	14.59	5292			
	E	14.59	6014			
<u>Target B</u>						
1	F	14.59	5292	5290	3	+6
	F	14.59	5715			
	H	14.89	4864			
2	A	15.19	6208	6240	9	+6
	A	14.89	6345			
	B	14.89	6345			
	B	14.89	6633			
	C	14.59	6213			
	E	14.59	5512			
	G	14.89	6081			
	G	14.89	6345			
	H	15.19	6477			
3	B	14.89	6345	6332	10	+7
	B	14.89	6633			
	C	14.59	5715			
	C	14.59	6495			
	D	14.59	6213			
	E	14.59	6495			
	E	14.59	6495			
	F	14.59	5954			
	G	14.89	6633			
	H	14.89	6345			
4	A	15.19	7095	6455	9	+7
	C	14.59	6495			
	E	14.59	6213			
	E	14.59	6495			
	F	14.59	6495			
	F	14.59	6495			
	G	14.89	5405			
	G	14.89	6633			
	H	15.19	6772			

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Fragment Velocities and Impact Distribution Data

Round Number 1

Date of Firing: 29 Sept 1959

<u>Row</u>	<u>Square</u>	<u>Frag. travel Distance, ft</u>	<u>Velocity, F/S</u> <u>Individual</u> <u>Ave</u>	<u>No. of Preformed Frags. Cons.</u>	<u>% Error</u>
<u>Target C</u>					
1	A	14.89	6633 6696	6	+ 7
	C	14.59	6805		
	D	14.59	6495		
	E	14.59	6805		
	F	14.59	6805		
	H	14.89	6633		
2	A	14.89	6949 6822	7	+ 7
	C	14.59	6805		
	D	14.59	6805		
	E	14.59	6805		
	F	14.59	6805		
	G	14.89	6949		
	H	14.89	6633		
3	A	14.89	6949 6802	9	+ 7
	B	14.89	6633		
	C	14.59	6805		
	C	14.59	6805		
	D	14.59	6805		
	E	14.59	6805		
	E	14.59	6805		
	F	14.59	6805		
	F	14.59	6805		
4	A	15.19	6772 6756	9	+ 7
	B	14.89	6633		
	C	14.59	6805		
	D	14.59	6805		
	E	14.59	6805		
	G	14.89	6633		
	G	14.89	6949		
	H	14.89	6633		
	H	15.19	6772		

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Fragment Velocities and Impact Distribution Data

Round Number 1
Date of Firing: 29 Sept 1959

<u>Row</u>	<u>Square</u>	<u>Frag. Travel Distance, ft</u>	<u>Velocity, F/S</u>	<u>No. of Preformed Frags. Cons.</u>	<u>% Error</u>
<u>Target D</u>					
1	A	15.19	6477	6738	10
	B	14.89	6633		
	C	14.59	6805		
	C	14.59	6805		
	D	14.59	6805		
	D	14.59	6805		
	E	14.59	6805		
	E	14.59	6805		
	F	14.59	6805		
	H	14.89	6633		
2	A	15.19	6772	6785	3
	B	14.89	6949		
	H	14.89	6633		
3	A	14.89	6633	6644	6
	C	14.59	6805		
	C	14.59	6805		
	E	14.59	6495		
	F	14.59	6495		
	H	14.89	6633		
4	A	14.89	6633	6541	6
	C	14.59	6495		
	D	14.59	6495		
	E	14.59	6495		
	F	14.59	6495		
	H	14.89	6633		
<u>Target E</u>					
1	B	14.89	6633	6540	6
	C	14.59	6495		
	D	14.59	6213		
	E	14.59	6495		
	G	14.89	6633		
	H	15.19	6772		

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Fragment Velocities and Impact Distribution Data

Round Number 1

Date of Firing: 29 Sept 1959

<u>Row</u>	<u>Square</u>	<u>Frag. Travel Distance, ft</u>	<u>Velocity, F/S Individual</u>	<u>Ave</u>	<u>No. of Preformed Frags. Cens.</u>	<u>% Error</u>
<u>Target E (Cont')</u>						
2	A	14.89	6633	6564	6	+ 7
	B	14.89	6633			
	D	14.59	6495			
	E	14.59	6495			
	F	14.59	6495			
	G	14.89	6633			
3	B	14.89	6081	5977	6	+ 6
	C	14.59	6081			
	D	14.59	5954			
	E	14.59	5954			
	G	14.89	5954			
	H	14.89	5837			
4	C	14.59	5715	5908	5	+ 6
	D	14.59	5954			
	E	14.59	5954			
	G	14.89	6081			
	H	14.89	5837			
<u>Target F</u>						
1	D	14.59	5715	5715	2	+ 6
	E	14.59	5715			
2	B	14.89	5837	5870	7	+ 6
	B	14.89	6081			
	C	14.59	5954			
	D	14.59	5954			
	F	14.59	5715			
	F	14.59	5715			
	G	14.89	5837			
3	E	14.59	5496	5566	5	+ 6
	G	14.59	5496			
	G	14.89	5613			
	H	14.89	5613			
	H	14.89	5613			

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Fragment Velocities and Impact Distribution Data

Round Number 1

Date of Firing: 29 Sept 1959

<u>Row</u>	<u>Square</u>	<u>Frag. Travel Distance, ft</u>	<u>Velocity, F/S Individual</u>	<u>Ave</u>	<u>No. of Pre-formed Frags. Cons.</u>	<u>% Error</u>
<u>Target F (Cont')</u>						
4	F	14.59	4763	4763	1	± 5
	D	14.59	4763*			
	E	14.59	4763*			
<u>Target G</u>						
1	D	14.59	4610*		0	± 5
2	A	14.89	4560	4849	2	± 5
	H	15.19	5138			
3	B	14.89	6081	6213	6	± 6
	C	14.59	6213			
	D	14.59	6213			
	E	14.59	6213			
	F	14.59	6213			
	H	14.89	6345			
	D	14.59	5292*			

* Other perforation than preformed fragment, not considered in average.

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Fragment Velocities and Impact Distribution Data

Round Number 2

Date of Firing: 6 Oct 1959

<u>Row</u>	<u>Square</u>	<u>Frag. Travel Distance, ft</u>	<u>Velocity, F/S Individual</u>	<u>Ave</u>	<u>No. of Preformed Frags, Cons.</u>	<u>% Error</u>
<u>Target 1</u>						
4	D H	14.59 14.89	5457 5089	5273	2	± 7
<u>Target 2</u>						
1	C	14.59	5731	5731	1	± 7
2	B B C D F F H	14.89 14.89 14.59 14.59 14.59 14.59 14.89	5320 5089 5210 4983 4983 4775 5089	5064	7	± 7
3	A	14.89	5574	5574	1	± 7
4	A H	14.89 14.89	5574 5320	5447	2	± 7
<u>Target 3</u>						
1	C D F G	14.59 14.59 14.59 14.89	5731 5731 5457 5574	5623	4	± 7
2	A B	14.89 14.89	5320 5574	5447	2	± 7
3	C C G	14.59 14.59 14.89	5457 5210 6885*	5334	2	± 8

* Other perforation than preformed fragment, not considered in average.

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Fragment Velocities and Impact Distribution Data

Round Number 2

Date of Firing: 6 Oct 1959

<u>Row</u>	<u>Square</u>	<u>Frag.</u> <u>Travel</u> <u>Distance, ft</u>	<u>Velocity, F/S</u> <u>Individual</u> <u>Ave</u>	<u>Preformed</u> <u>Frags. Cons.</u>	<u>%</u> <u>Error</u>
<u>Target 3 (Cont')</u>					
4	B	14.89	5574	6858	4
	D	14.59	8186		
	D	14.59	6033		
	F	14.59	7641		
	D	14.59	7641*		
<u>Target 4</u>					
1	A	14.89	5574	6011	3
	A	14.89	5574		
	H	14.89	6885		
2	C	14.59	5457	5868	3
	D	14.59	4983		
	F	14.59	7163		
	E	14.59	6741*		
3	C	14.59	5210	5210	1
4	A	14.89	5852	5168	3
	D	14.59	4775		
	G	14.89	4877		
<u>Target 5</u>					
1	A	15.19	5429	5035	3
	C	14.59	4649		
	H	15.19	5028		
2	C	14.59	4822	4786	2
	G	14.89	4749		
3	C	14.59	4822	4646	6
	C	14.59	4649		
	D	14.59	4489		
	G	14.89	4749		
	G	14.89	4585		
	H	14.89	4585		

* Other perforation than preformed fragment, not considered in average.

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Fragment Velocities and Impact Distribution Data

Round Number 2

Date of Firing: 6 Oct 1959

<u>Row</u>	<u>Square</u>	<u>Frag. Travel Distance, ft</u>	<u>Velocity, F/S Individual</u>	<u>Ave</u>	<u>Preformed Frags. Cons.</u>	<u>% Error</u>
<u>(Target 5 Cont')</u>						
4	E	14.59	5424	5424	1	£ 6
<u>Target 6</u>						
1	B	14.89	5781	5397	3	£ 6
	D	14.59	5660			
	H	14.89	4749			
2	A	15.19	5655	5443	5	£ 6
	A	14.89	4924			
	E	14.59	5660			
	F	14.59	5660			
	G	14.89	5318			
4	A	15.19	5429	5229	7	£ 6
	B	14.89	5114			
	C	14.59	4649			
	D	14.59	5008			
	E	14.59	5660			
	H	14.89	5318			
	D	14.59	5424			
<u>Target 7</u>						
1	D	14.59	5208	5208	1	£ 6
	F	14.59	5208*			
2	A	15.19	4848	5106	5	£ 6
	B	14.89	5540			
	C	14.59	4822			
	F	14.59	5208			
	H	14.89	5114			
3	B	14.59	6199	6199	3	£ 7
	D	14.59	6199			
	E	14.59	6199			

* Other perforation than preformed fragment, not considered in average.

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Fragment Velocities and Impact Distribution Data

Round Number 2
Date of Firing: 6 Oct 1959

<u>Row</u>	<u>Square</u>	Frag. Travel <u>Distance, ft</u>	Velocity, F/S <u>Individual</u>	<u>Ave</u>	Preformed Frags. Cons.	<u>% Error</u>
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Target 7 (Cont'd)

4	A	15.19	6464	6194	4	± 7
	A	14.89	6331			
	F	14.59	6199			
	G	14.89	5781			

Target 8

1	H	14.89	6043	6043	1	± 7
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Fragment Velocities and Impact Distribution Data

Round Number 2

<u>Row</u>	<u>Square</u>	<u>Frag. Travel Distance, ft</u>	<u>Velocity, F/S Individual</u>	<u>Ave</u>	<u>No. of Preformed Frags. Cons.</u>	<u>% Error</u>
<u>Target A</u>						
4	B	14.89	5039	5184	2	+ 6
	D	14.59	5329			
<u>Target B</u>						
2	A	14.89	6184	6255	10	+ 7
	A	15.19	6945			
	B	14.89	6802			
	C	14.59	6055			
	D	14.59	6055			
	E	14.59	4758			
	E	14.59	6343			
	G	14.89	6479			
	H	15.19	6313			
	H	15.19	6614			
3	B	14.89	6802	6524	11	+ 7
	C	14.59	6343			
	C	14.59	6661			
	D	14.59	7011			
	E	14.59	6661			
	E	14.59	7011			
	F	14.59	6661			
	G	14.89	4535			
	G	14.89	6802			
	G	14.89	6749			
	H	14.89	6802			
4	B	14.89	6802	6957	5	+ 7
	C	14.59	7011			
	D	14.59	7011			
	G	14.89	7160			
	H	14.89	6802			

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Fragment Velocities and Impact Distribution Data

Round Number 2

<u>Row</u>	<u>Square</u>	<u>Frag. Travel Distance, ft</u>	<u>Velocity, Individual</u>	<u>F/S Ave</u>	<u>No. of Preformed Frags. Cons.</u>	<u>% Error</u>
<u>Target C</u>						
1	A	14.89	5232	6717	9	<u>+7</u>
	A	15.19	7310			
	B	14.89	7160			
	C	14.59	7011			
	E	14.59	6343			
	E	14.59	7011			
	G	14.89	5916			
	G	14.89	7160			
	H	15.19	7310			
2	A	15.19	7310	7006	11	<u>+7</u>
	A	15.19	7310			
	B	14.89	7160			
	B	14.89	7160			
	C	14.59	6661			
	C	14.59	6661			
	E	14.59	6661			
	E	14.59	6661			
	F	14.59	7011			
	G	14.89	7160			
	H	15.19	7310			
3	A	14.89	7160	7041	5	<u>+7</u>
	C	14.59	7011			
	D	14.59	7011			
	E	14.59	7011			
	F	14.59	7011			
4	A	15.19	7310	6917	9	<u>+7</u>
	B	14.59	7011			
	D	14.59	7011			
	E	14.59	6661			
	F	14.59	6661			
	F	14.59	7011			
	G	14.89	7160			
	H	14.89	6479			
	H	15.19	6945			

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Fragment Velocities and Impact Distribution Data

Round Number 2

<u>Row</u>	<u>Square</u>	<u>Frag. Travel Distance, ft</u>	<u>Velocity, F/S Individual</u>	<u>Ave</u>	<u>No. of Preformed Frags. Cons.</u>	<u>% Error</u>
<u>Target D</u>						
1	B	14.89	7160	7001	6	+7
	C	14.59	7011			
	D	14.59	7011			
	E	14.59	7011			
	G	14.59	7011			
	H	14.89	6802			
2	A	15.19	6945	7021	12	+7
	A	15.19	6945			
	B	14.89	7160			
	B	14.89	7160			
	C	14.59	7011			
	C	14.59	7011			
	D	14.59	7011			
	E	14.59	7011			
	F	14.59	7011			
	G	14.59	7011			
	G	14.89	6661			
	H	15.19	7310			
3	E	14.59	7011	6906	2	+7
	H	14.89	6802			
4	A	14.89	6802	6883	6	+7
	B	14.59	6661			
	D	14.59	7011			
	E	14.59	7011			
	E	14.59	7011			
	H	14.89	6802			
<u>Target E</u>						
1	B	14.89	6802	6814	6	+7
	C	14.59	6661			
	E	14.59	6661			
	F	14.59	7011			
	G	14.89	6802			
	H	15.19	6945			
2	B	14.89	6802	6932	6	+7
	C	14.59	6661			
	D	14.59	7011			

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Fragment Velocities and Impact Distribution Data

Round Number 2

Date of Firing: 6 Oct 1959

<u>Row</u>	<u>Square</u>	<u>Frag. Travel Distance, ft</u>	<u>Velocity, F/S</u>	<u>No. of Preformed Frags. Cons.</u>	<u>% Error</u>
<u>Target E (Cont')</u>					

2	F	14.59	7011		
	G	14.89	7160		
	H	15.19	6945		
3	A	14.89	6184	6405	7
	A	14.89	6802		
	B	14.59	6343		
	D	14.59	6343		
	E	14.59	6343		
	F	14.59	6343		
	H	14.89	6479		
4	A	15.19	7717	6465	5
	D	14.59	6055		
	E	14.59	6055		
	G	14.89	6184		
	H	15.19	6313		

Target F

1	C	14.59	6631	6675	5
	D	14.59	6979		
	E	14.59	6979		
	F	14.59	6631		
	H	14.89	6156		
2	A	15.19	6584	6868	4
	B	14.89	6156		
	E	14.59	7367		
	F	14.59	7367		
	D	14.59	7367*		
3	A	15.19	6584	6705	12
	A	15.19	6584		
	B	14.89	4670		

* Other perforation than preformed fragment, not considered in average.

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Fragment Velocities and Impact Distribution Data

Round Number 2

Date of Firing: 6 Oct 1959

<u>Row</u>	<u>Square</u>	<u>Frag.</u> Travel <u>Distance, ft</u>	<u>Velocity, F/S</u> <u>Individual</u> <u>Ave</u>	<u>No of</u> <u>Preformed</u> <u>Frags. Cons.</u>	<u>%</u> <u>Error</u>
------------	---------------	--	--	---	--------------------------

Target F (Cont')

3	B	14.89	7524		
	B	14.89	7524		
	C	14.59	7367		
	C	14.59	7367		
	D	14.59	7367		
	E	14.59	7367		
	G	14.59	5765		
	G	14.89	6449		
	H	14.89	5889		
4	C	14.59	5765	5968	4
	C	14.59	5765		£ 7
	E	14.59	6027		
	F	14.59	6314		
	A	15.19	5761*		

Target G

1	G	14.59	5756	5756	1	£ 6
2	G	14.89	5015	5015	1	£ 6
3	B	14.89	6771	6461	5	£ 7
	C	14.59	6631			
	E	14.59	6631			
	E	14.59	6631			
	G	14.89	5613			
4	A	14.89	6771	6038	2	£ 7
	G	14.59	5304			

* Other perforation than preformed fragment, not considered in average.

Incl 2

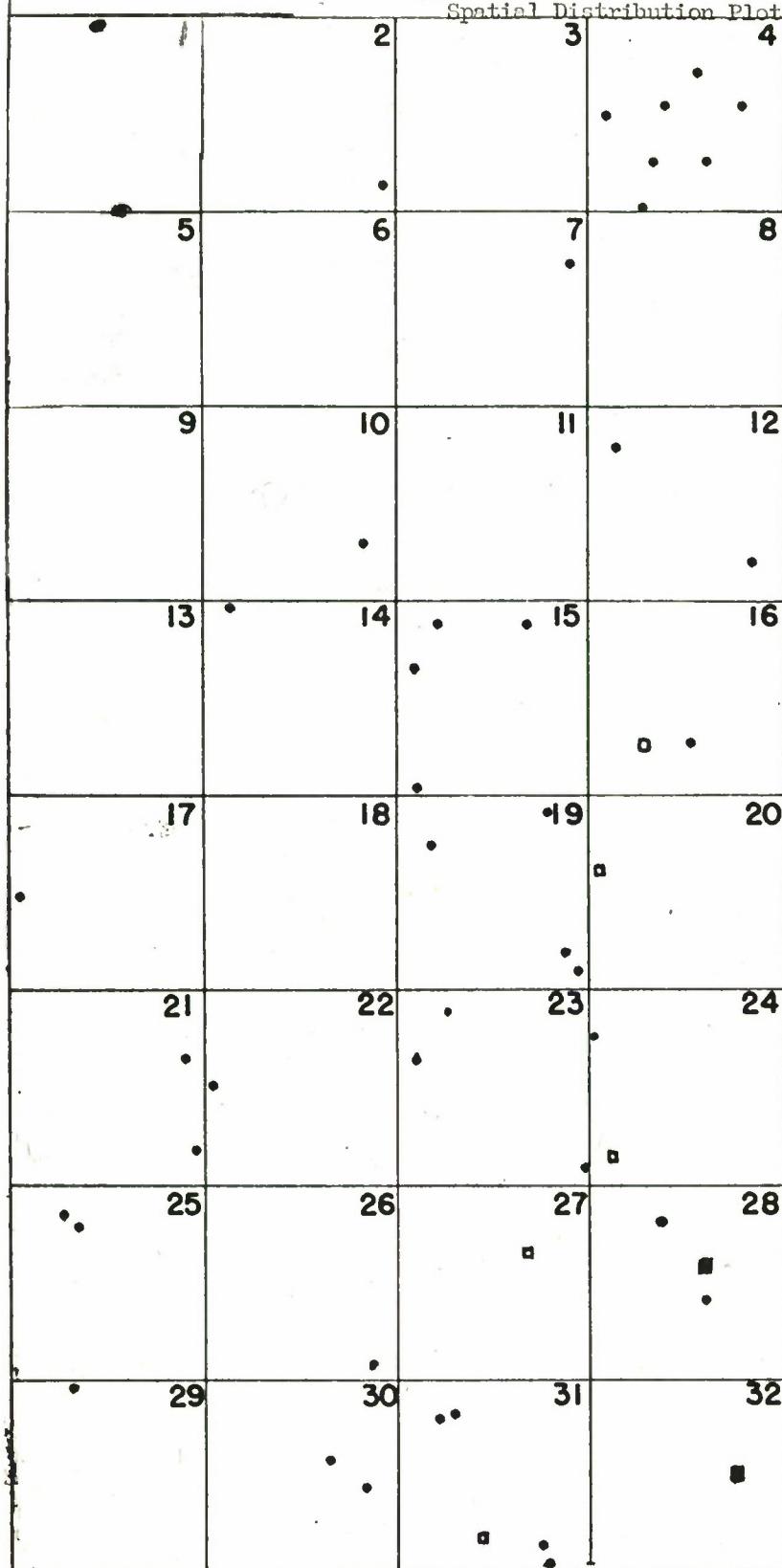
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APPENDIX C
Spatial Distribution Plots



WARHEAD XM5E3

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 5

■ - CUBE PENETRATIONS
TOTAL NO. = 3

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 44

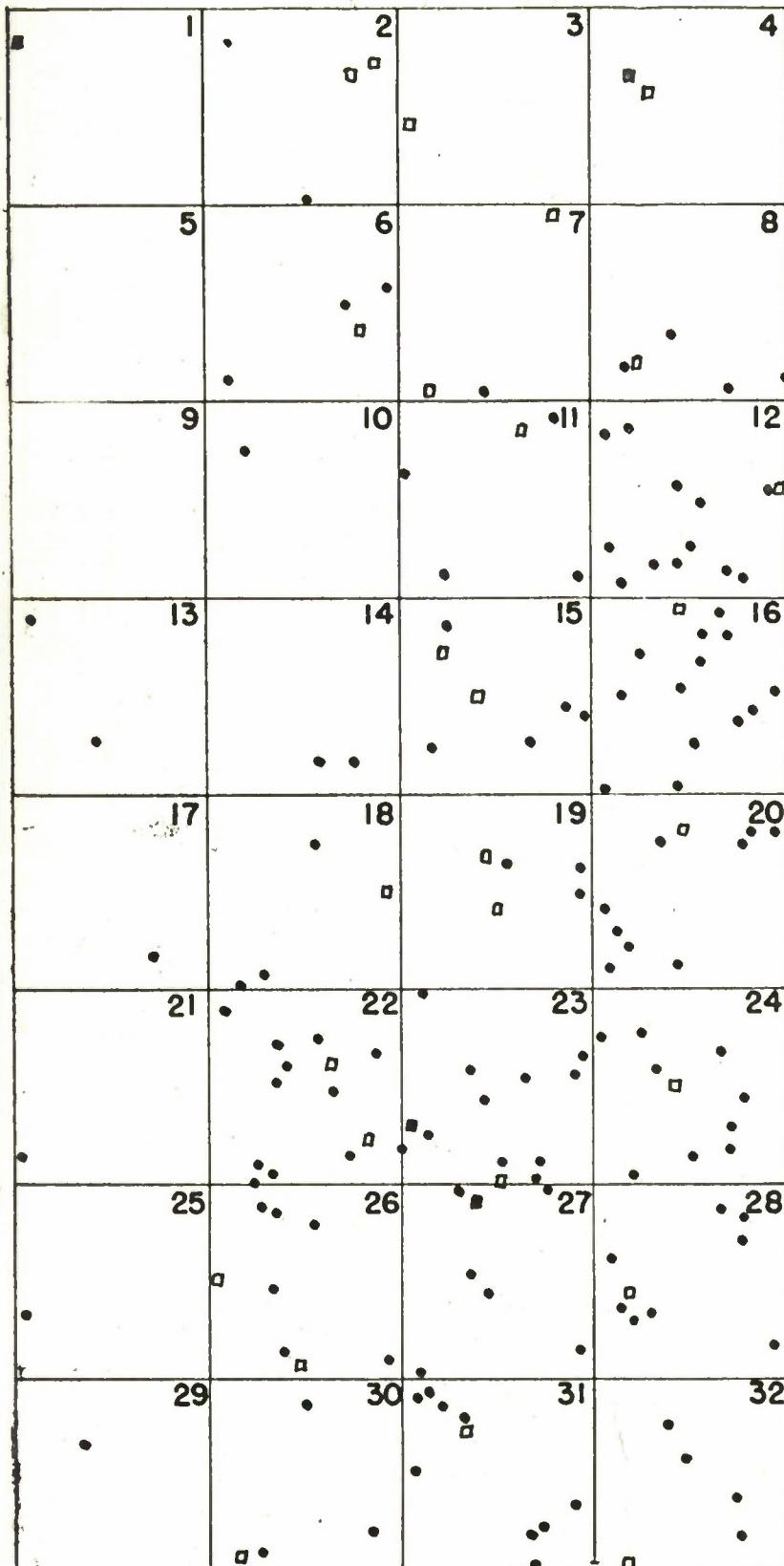
ZONE -

TOTAL NO. " " =

" " =

PLATE NO. 1

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WARHEAD XM5E3

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

■ - CUBE PERFORATIONS
TOTAL NO. = 27

■ - CUBE PENETRATIONS
TOTAL NO. = 4

○ - OTHER PERFORATIONS
TOTAL NO. = 0

○ - OTHER PENETRATIONS
TOTAL NO. = 133

ZONE -

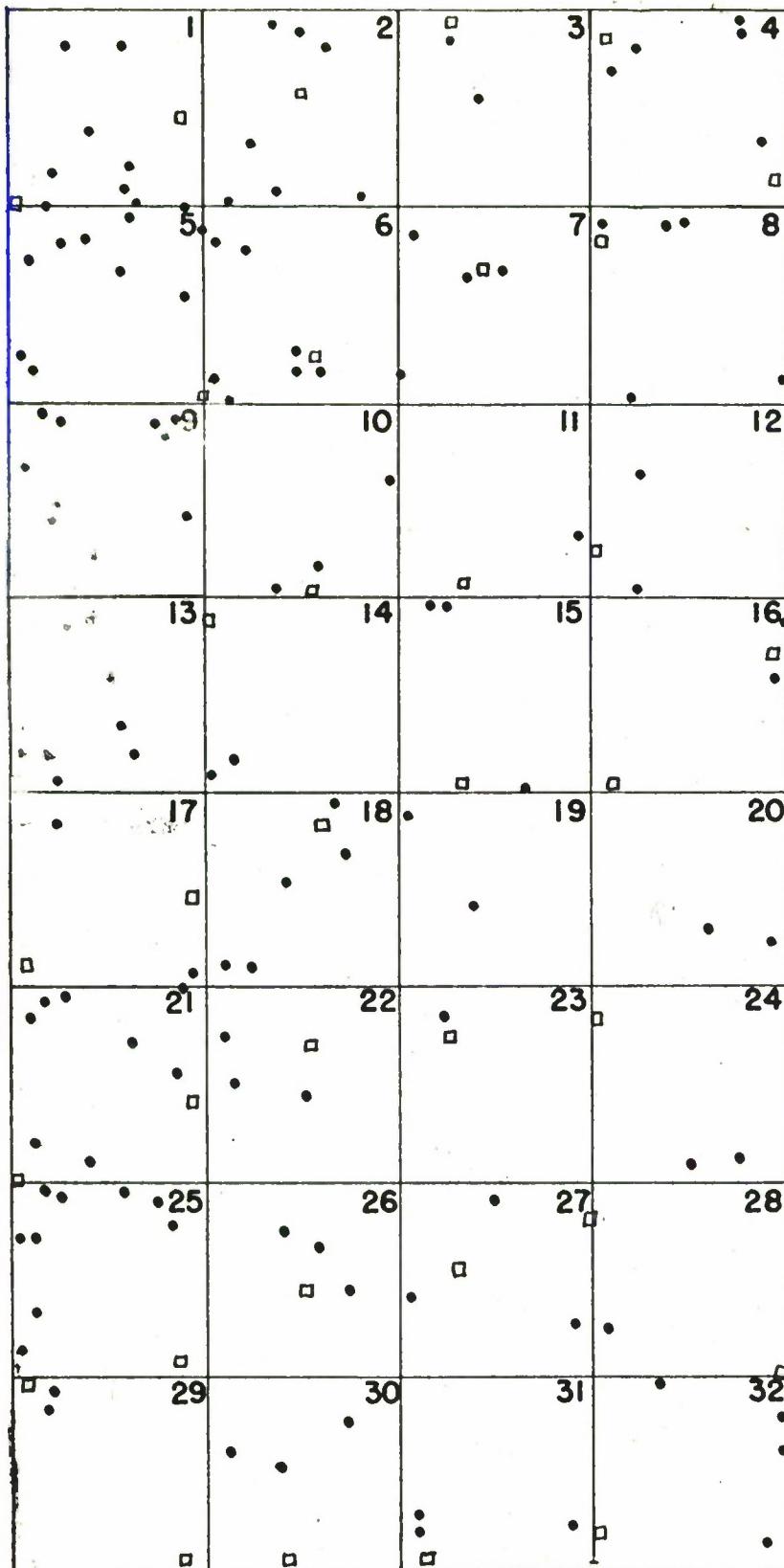
TOTAL NO. " "

" "

PLATE NO. 2

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD XM5B3

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 36

■ - CUBE PENETRATIONS
TOTAL NO. = 0

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 133

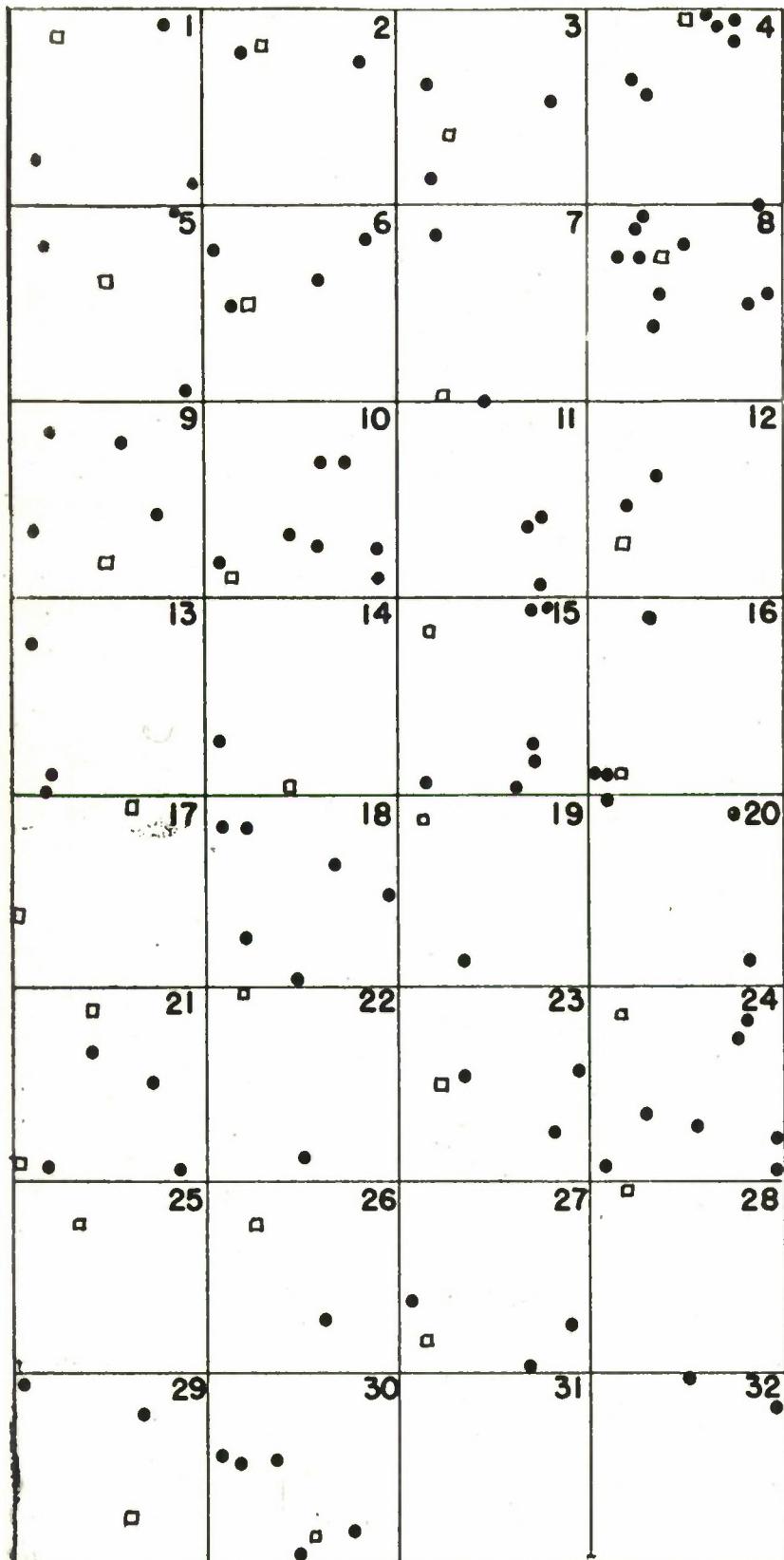
ZONE -

TOTAL NO. " " "
" " "

PLATE NO. 3

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD XM5E3

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 28

■ - CUBE PENETRATIONS
TOTAL NO. = 0

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 100

ZONE -

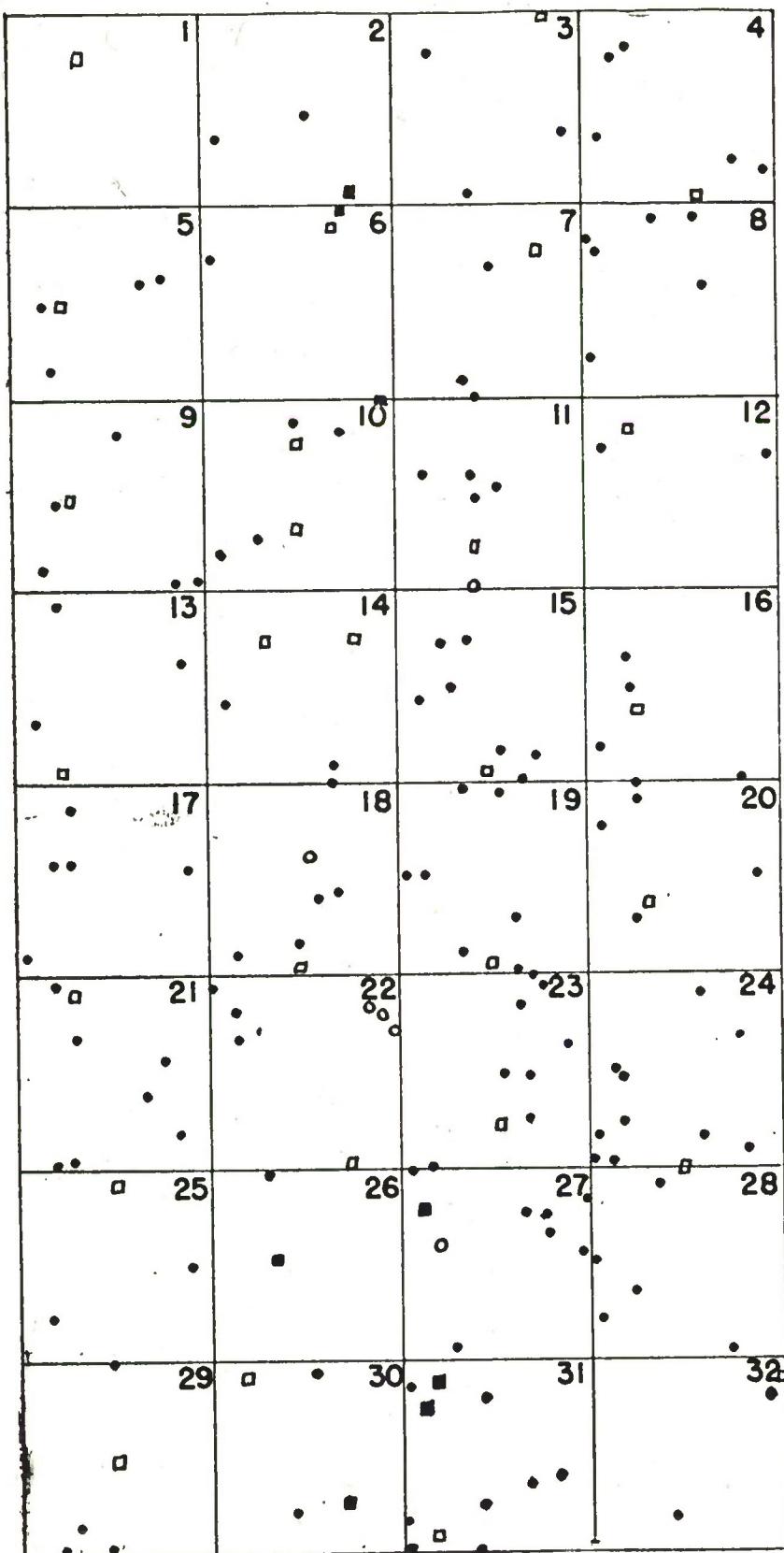
TOTAL NO. " "

" "

PLATE NO. 4

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD XM5E3

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 28

■ - CUBE PENETRATIONS
TOTAL NO. = 8

○ - OTHER PERFORATIONS
TOTAL NO. = 5

● - OTHER PENETRATIONS
TOTAL NO. = 137

ZONE -

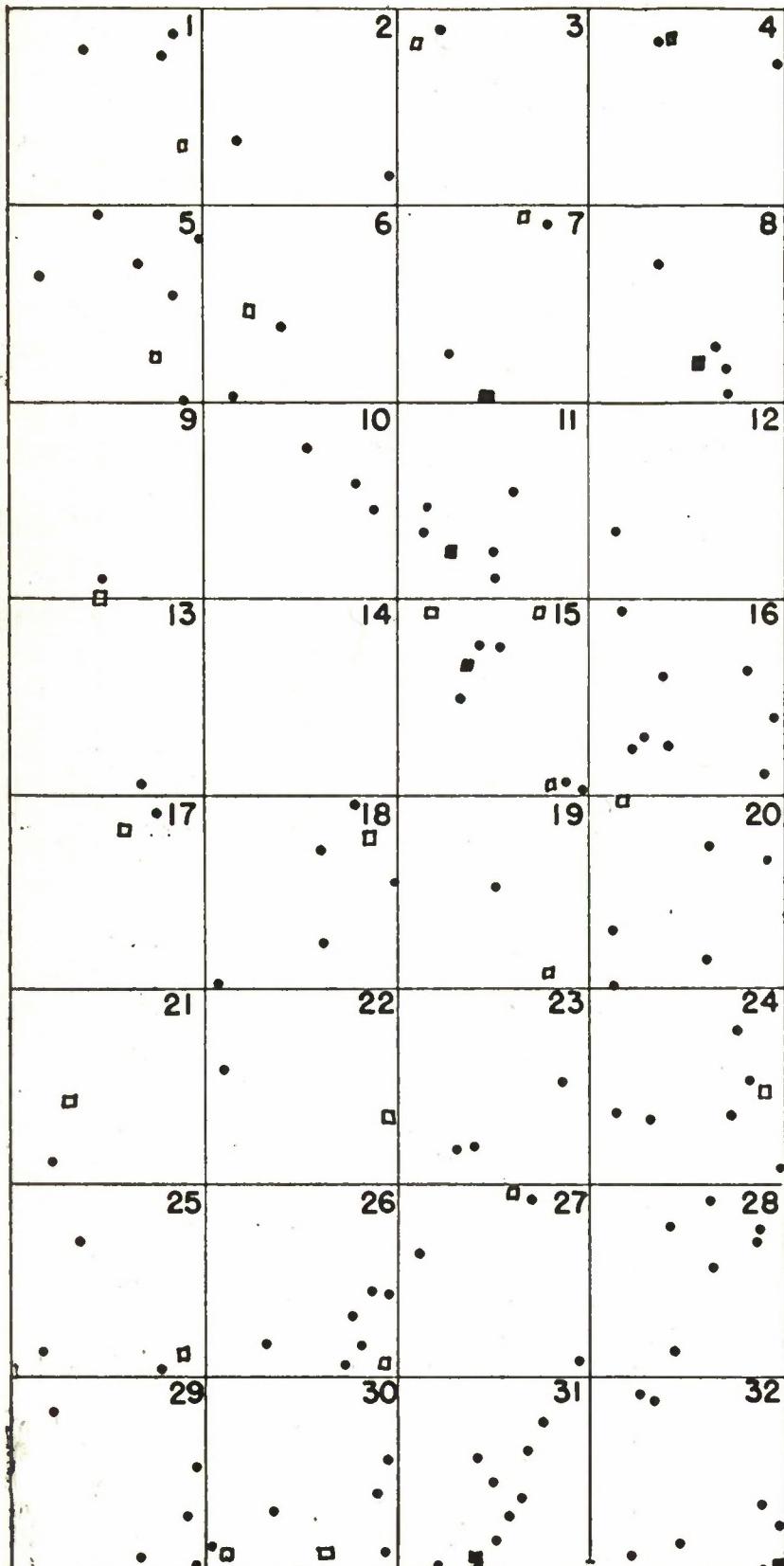
TOTAL NO. " "

" "

PLATE NO. 5

~~CONFIDENTIAL~~

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WARHEAD XM5E3

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 21

■ - CUBE PENETRATIONS
TOTAL NO. = 7

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 113

ZONE -

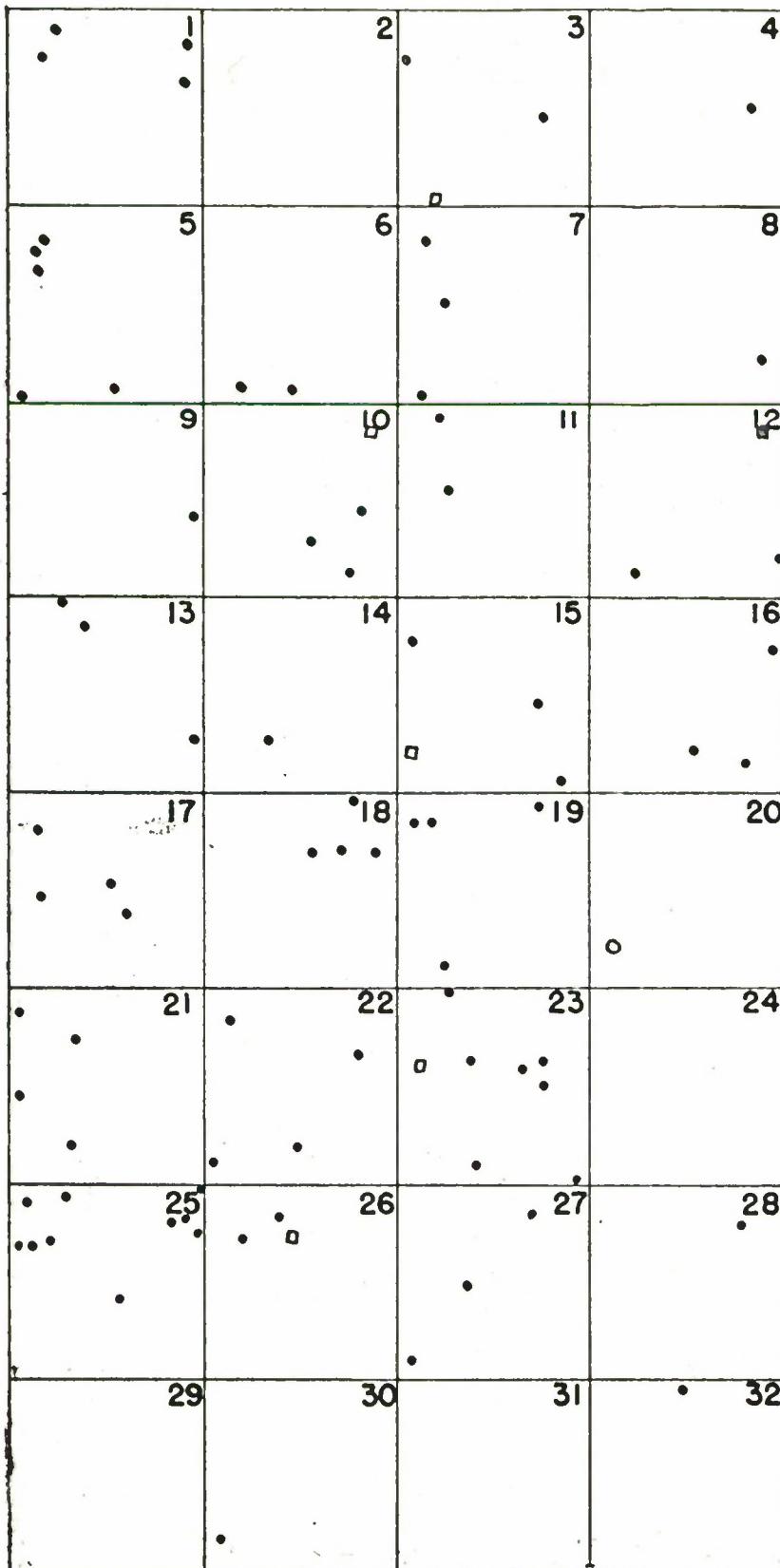
TOTAL NO. " "

" "

PLATE NO. 6

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD XM5E3

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 5

■ - CUBE PENETRATIONS
TOTAL NO. = 1

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 82

ZONE -

TOTAL NO. " "

" "

PLATE NO. 7

~~CONFIDENTIAL~~

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	1	2	3	4
	5	6	7	8
	9	10	11	12
	13	14	15	16
	17	18	19	20
	21	22	23	24
	25	26	27	28
	29	30	31	32

WARHEAD XM5E3

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

D - CUBE PERFORATIONS
TOTAL NO. = 6

D - CUBE PENETRATIONS
TOTAL NO. = 1

O - OTHER PERFORATIONS
TOTAL NO. = 0

O - OTHER PENETRATIONS
TOTAL NO. = 62

ZONE -

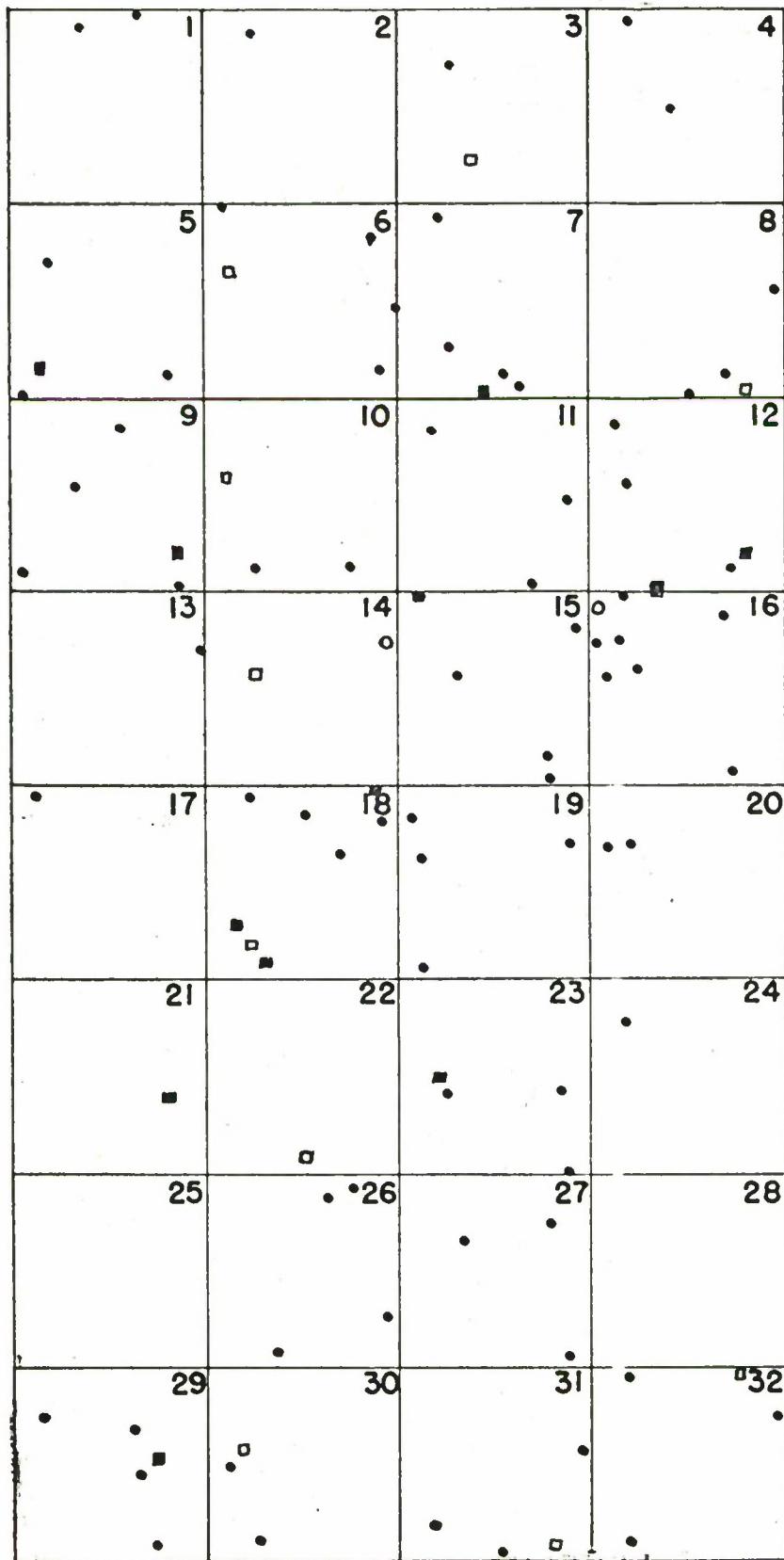
TOTAL NO. " "

" "

PLATE NO. 8

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD XM5E3

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 9

■ - CUBE PENETRATIONS
TOTAL NO. = 12

○ - OTHER PERFORATIONS
TOTAL NO. = 2

● - OTHER PENETRATIONS
TOTAL NO. = 77

ZONE -

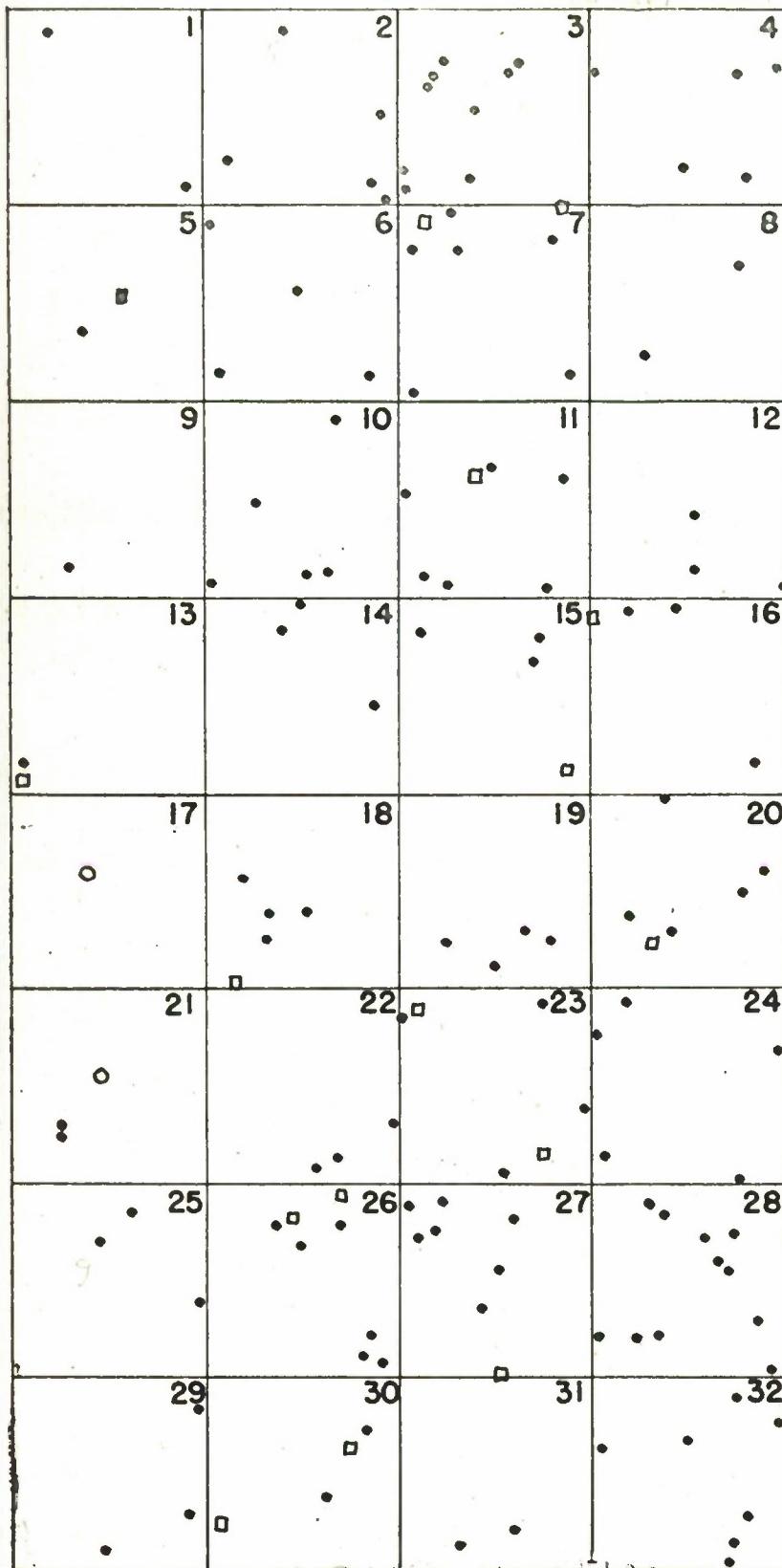
TOTAL NO. " "

" "

PLATE NO. G

~~CONFIDENTIAL~~

CONFIDENTIAL



WARHEAD XM523

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 17

□ - CUBE PENETRATIONS
TOTAL NO. = 1

○ - OTHER PERFORATIONS
TOTAL NO. = 2

○ - OTHER PENETRATIONS
TOTAL NO. = 128

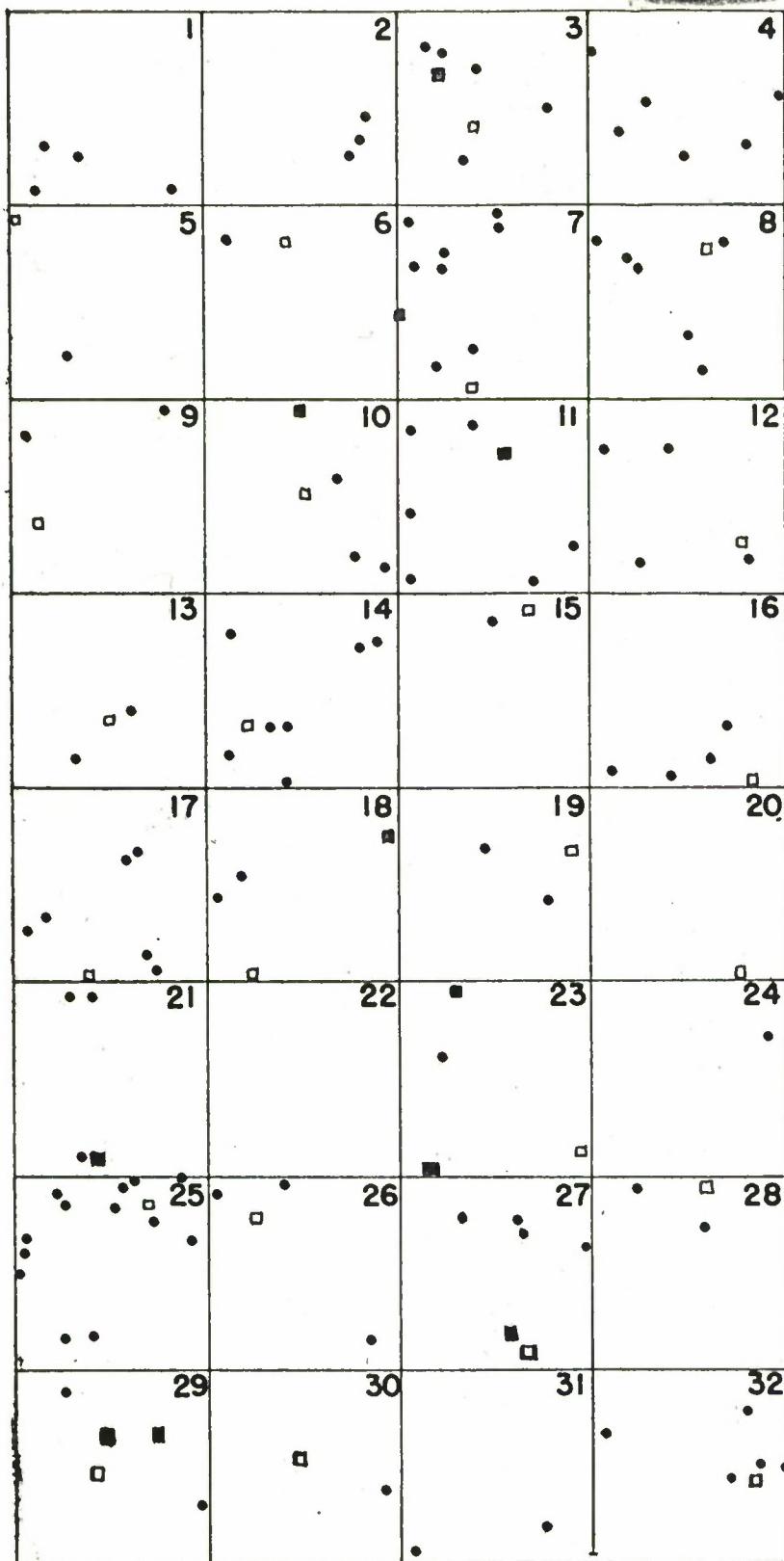
ZONE -

TOTAL NO. " " =
" " "

PLATE NO. F

CONFIDENTIAL

~~CONFIDENTIAL~~



WARHEAD XM5E3

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959
SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 24

■ - CUBE PENETRATIONS
TOTAL NO. = 11

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 110

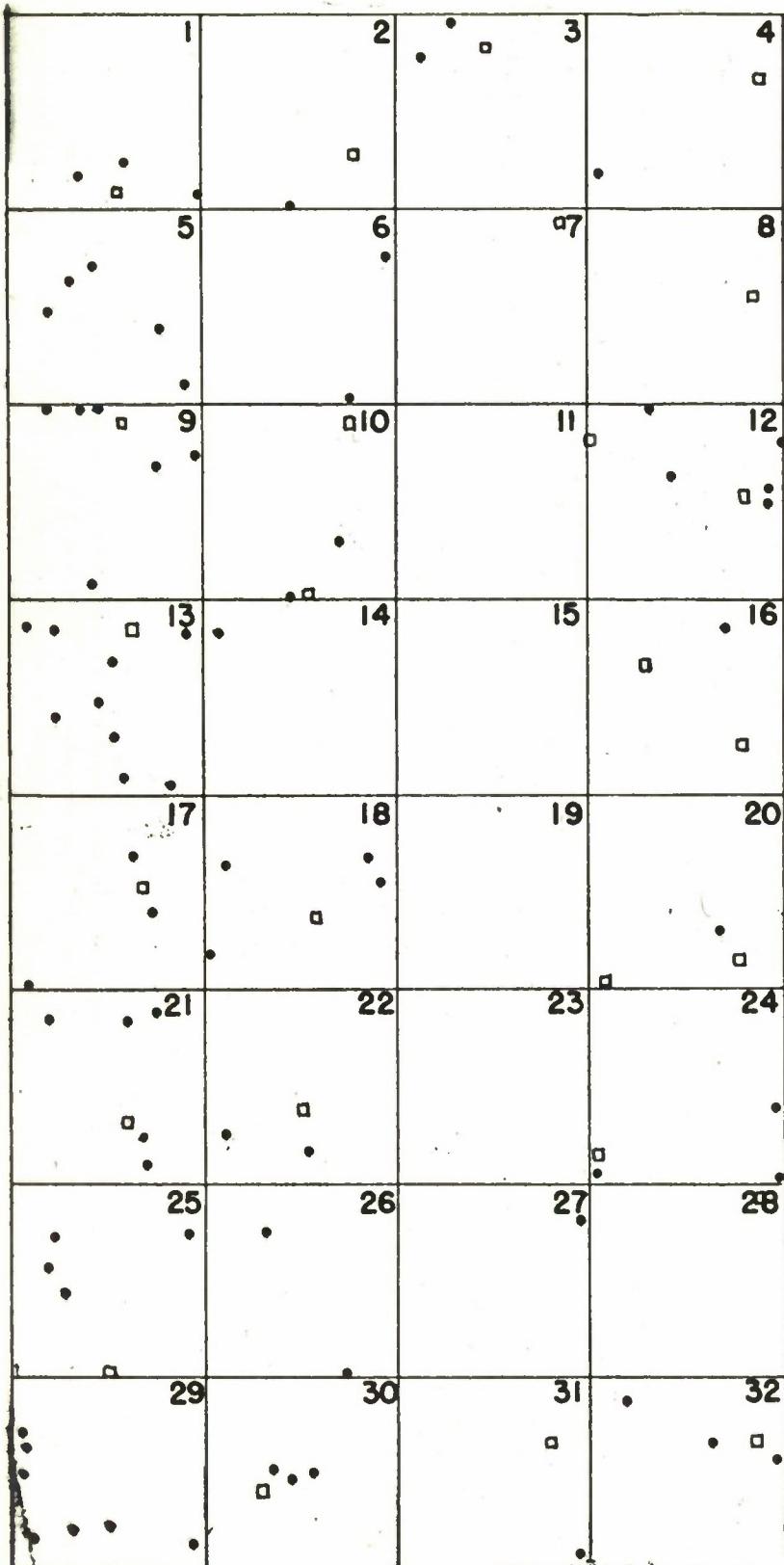
ZONE -

TOTAL NO. " " =
" " "

PLATE NO. E

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD XM523

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 26

■ - CUBE PENETRATIONS
TOTAL NO. = 0

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 78

ZONE -

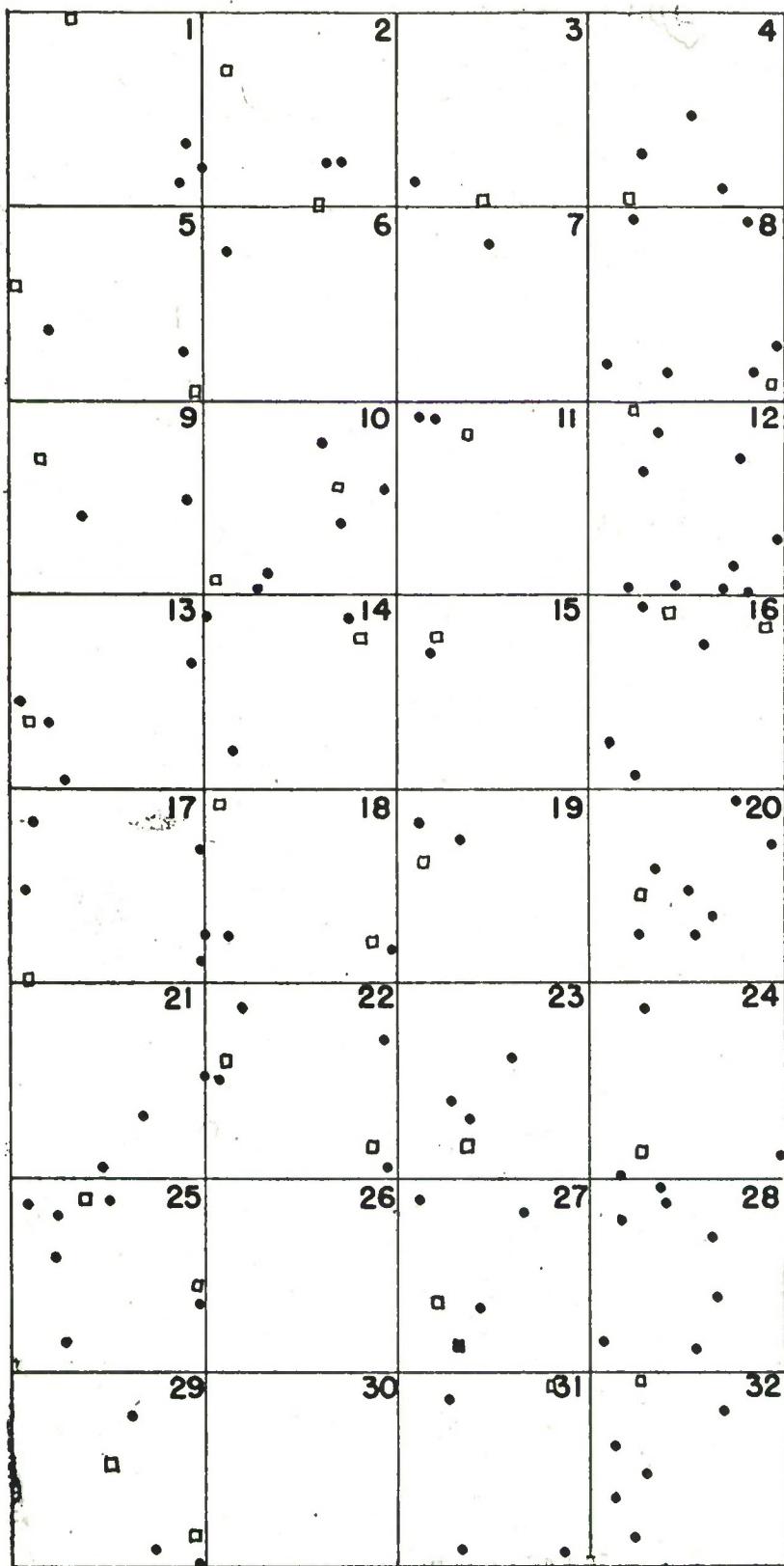
TOTAL NO. " "

" "

PLATE NO. D

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD XME3

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 34

■ - CUBE PENETRATIONS
TOTAL NO. = 1

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 105

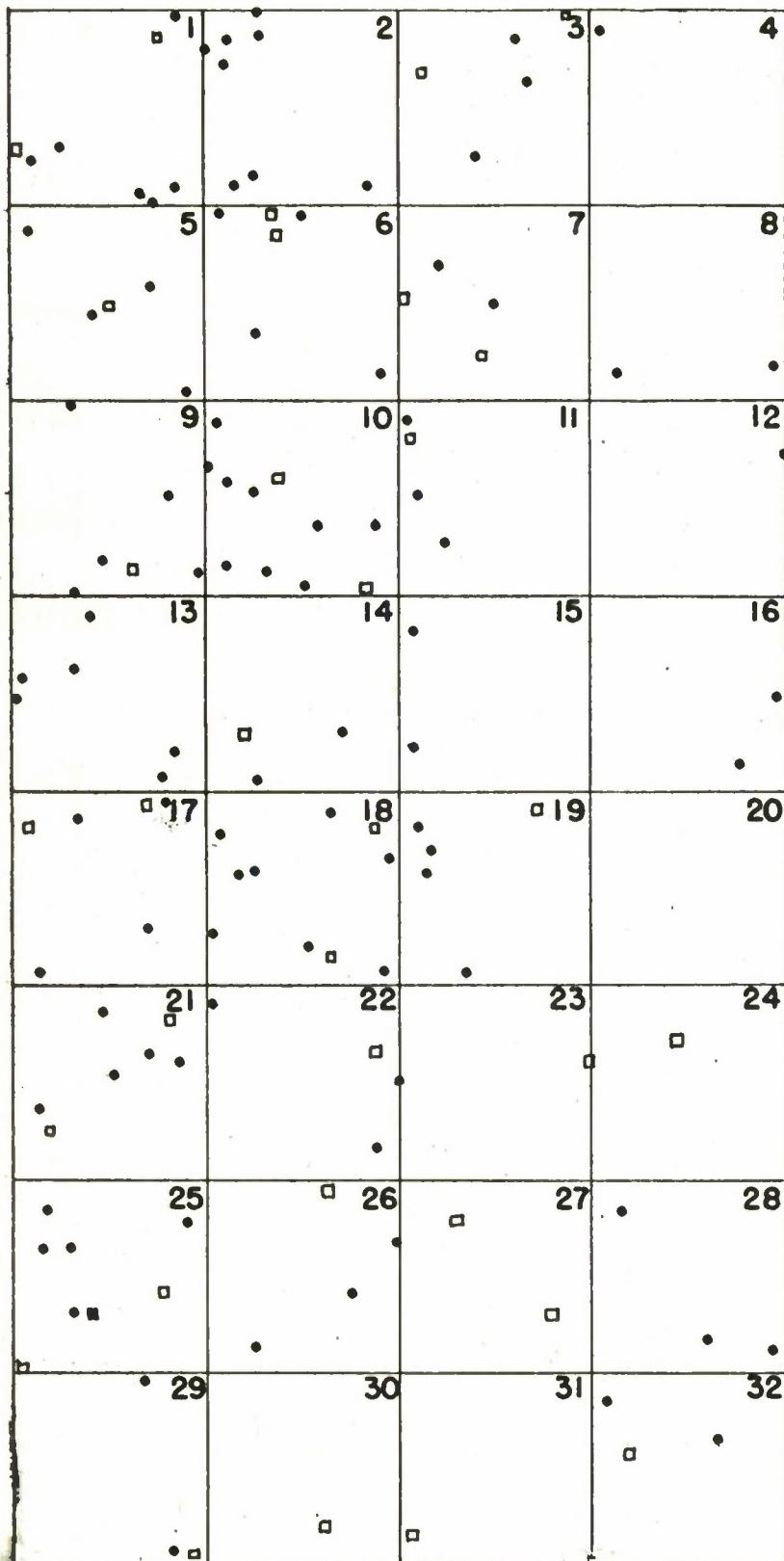
ZONE -

TOTAL NO. " " "

" "

PLATE NO. C

~~CONFIDENTIAL~~



WARHEAD XM5E3
ROUND NO. 1
UNIT NO. 17
DATE 29 September 1959
SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 32

■ - CUBE PENETRATIONS
TOTAL NO. = 2

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 100

ZONE -

TOTAL NO. " " "
" " "

PLATE NO. B

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

1	•	2	3	4
	•	•	•	.
□				.
5		6	7	8
	•		•	
9		10	•	11
				12
13		14		15
	•			16
17		18		19
□				20
21		22	23	24
	•			
25		26		27
	•			28
29	•	30	31	32
			•	
	•		•	
		•	•	
	•		•	

WARHEAD XM5E3

ROUND NO. 2

UNIT NO. 17

DATE 29 September 19559

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 4

■ - CUBE PENETRATIONS
TOTAL NO. = 2

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 27

ZONE -

TOTAL NO. " " =
" " "

PLATE NO. A

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16
17	18	19	20
21	22	23	24
25	26	27	28
29	30	31	32

WARHEAD XM583

ROUND NO. 1

UNIT NO. 17

DATE 29 September 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 0

■ - CUBE PENETRATIONS
TOTAL NO. = 1

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 26

ZONE -

TOTAL NO. " " "
" " "

PLATE NO. H

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

1	2	3	4
		.	.
5	6	7	8
	.		.
9	10	11	12
.		.	.
13	14	15	16
	.	.	□
17	18	19	20
21	22	23	24
	.	.	□
25	26	27	28
		.	□
29	30	31	32
.	.	.	■

WARHEAD ~~IMSE3~~

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959

SCALE 1 INCH = 1 FOOT



CODE:

D - CUBE PERFORATIONS
TOTAL NO. = 4

□ - CUBE PENETRATIONS
TOTAL NO. = 2

O - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 32

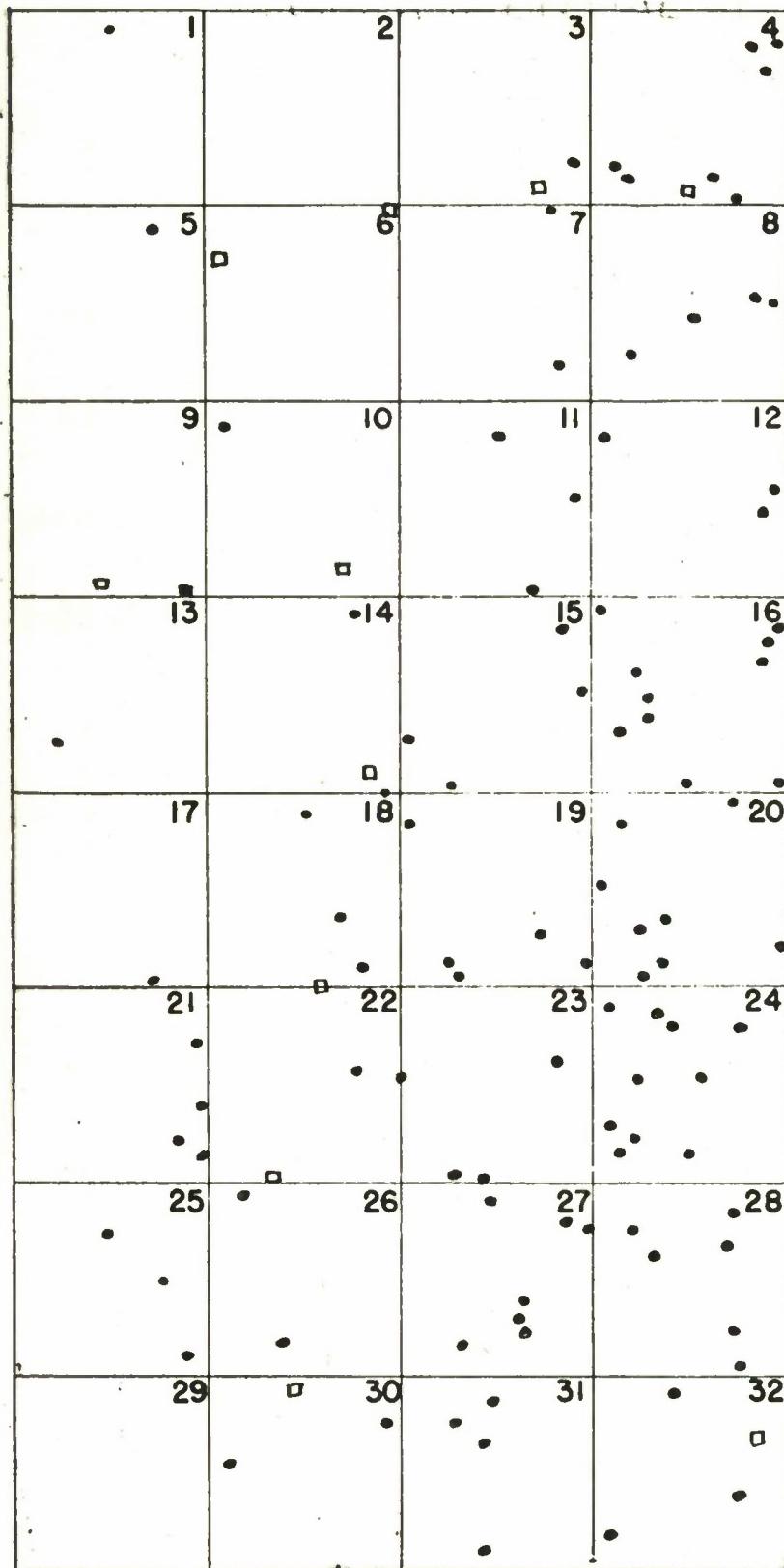
ZONE -

TOTAL NO. " " =
" " =

PLATE NO. 1

~~CONFIDENTIAL~~

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WARHEAD XM5E3
ROUND NO. 2
UNIT NO. 16
DATE 6 October 1959
SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 11

● - CUBE PENETRATIONS
TOTAL NO. = 1

• - OTHER PERFORATIONS
TOTAL NO. = 0

○ - OTHER PENETRATIONS
TOTAL NO. = 103

ZONE -

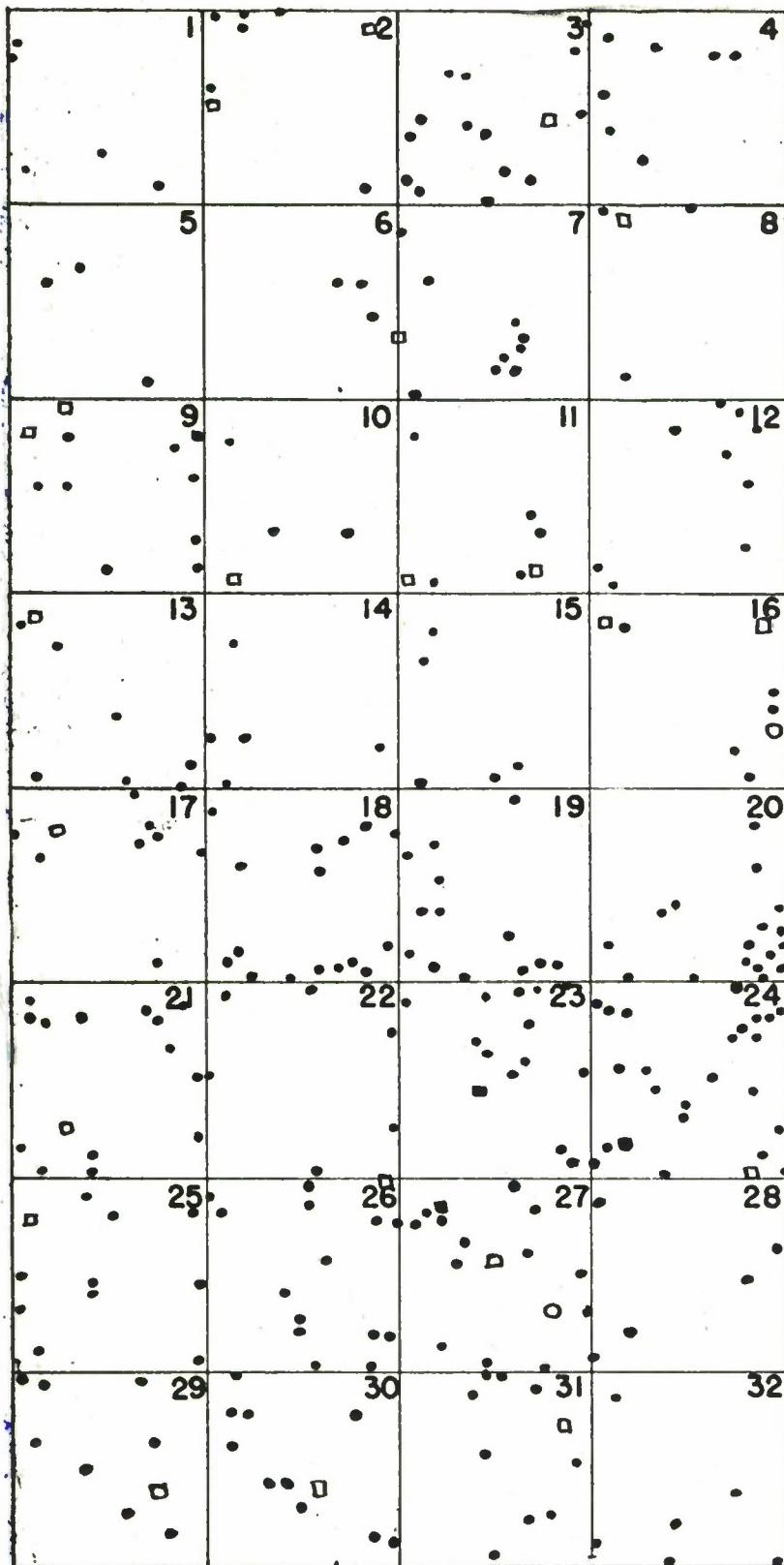
TOTAL NO. " " =

" " =

PLATE NO. 2

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD, XM5E3

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 22

■ - CUBE PENETRATIONS
TOTAL NO. = 24

○ - OTHER PERFORATIONS
TOTAL NO. = 2

● - OTHER PENETRATIONS
TOTAL NO. = 278

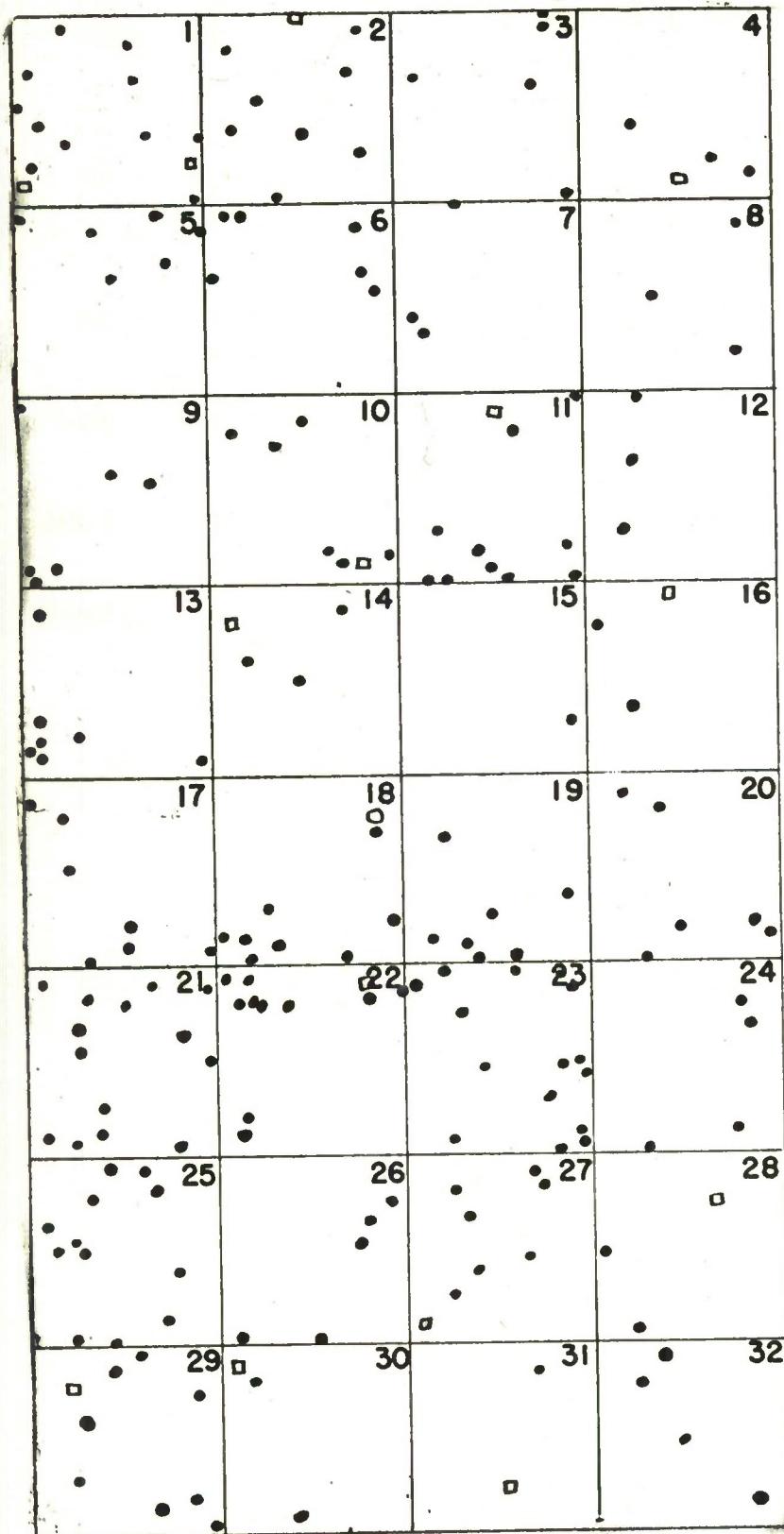
ZONE -

TOTAL NO. " " =
" " =

PLATE NO. 3

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD, XME3

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 13

■ - CUBE PENETRATIONS
TOTAL NO. = 0

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 197

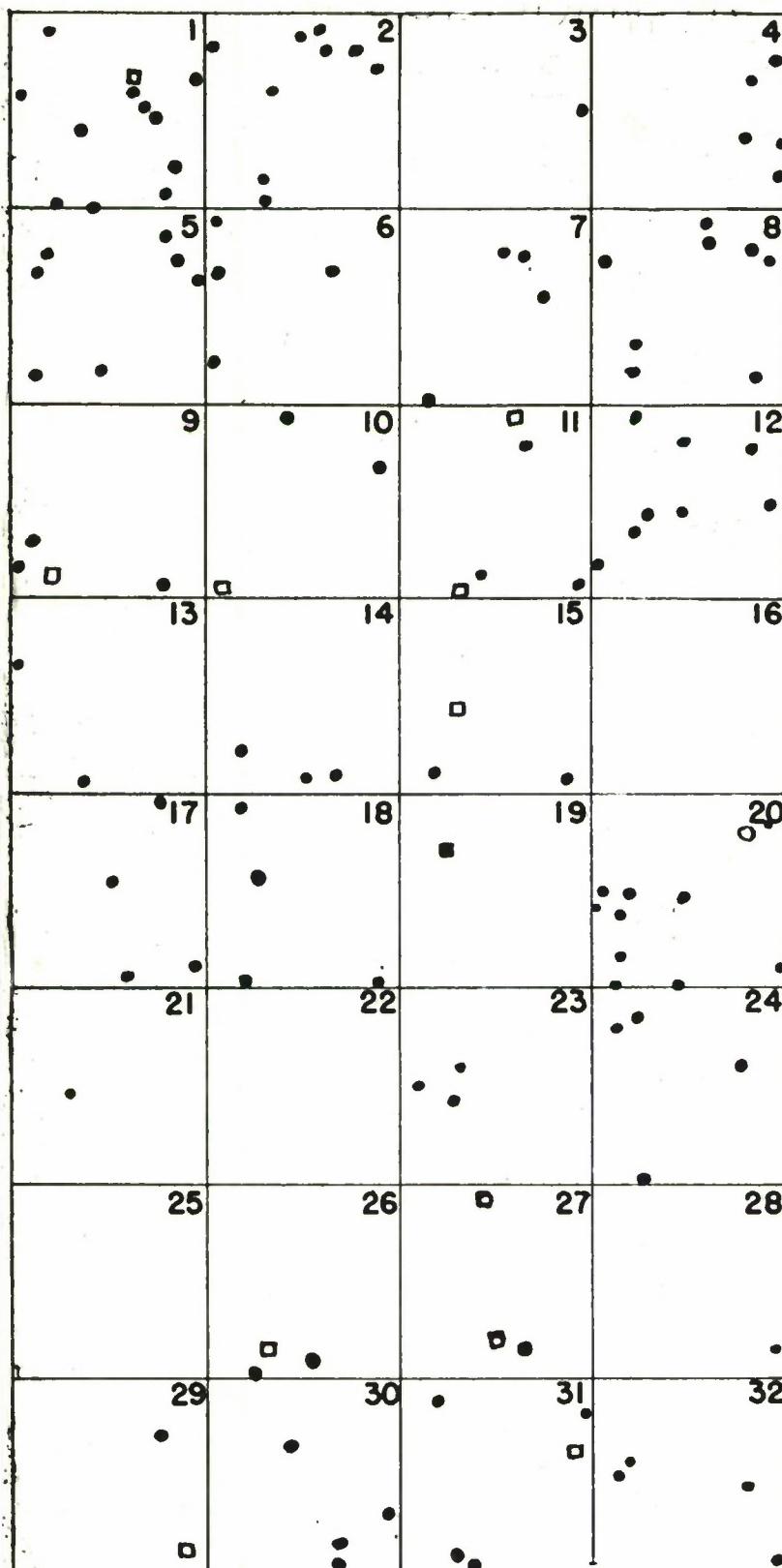
ZONE -

TOTAL NO. " " =
" " =

PLATE NO. 4

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD XM5E3

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 11

■ - CUBE PENETRATIONS
TOTAL NO. = 1

○ - OTHER PERFORATIONS
TOTAL NO. = 1

● - OTHER PENETRATIONS
TOTAL NO. = 114

ZONE -

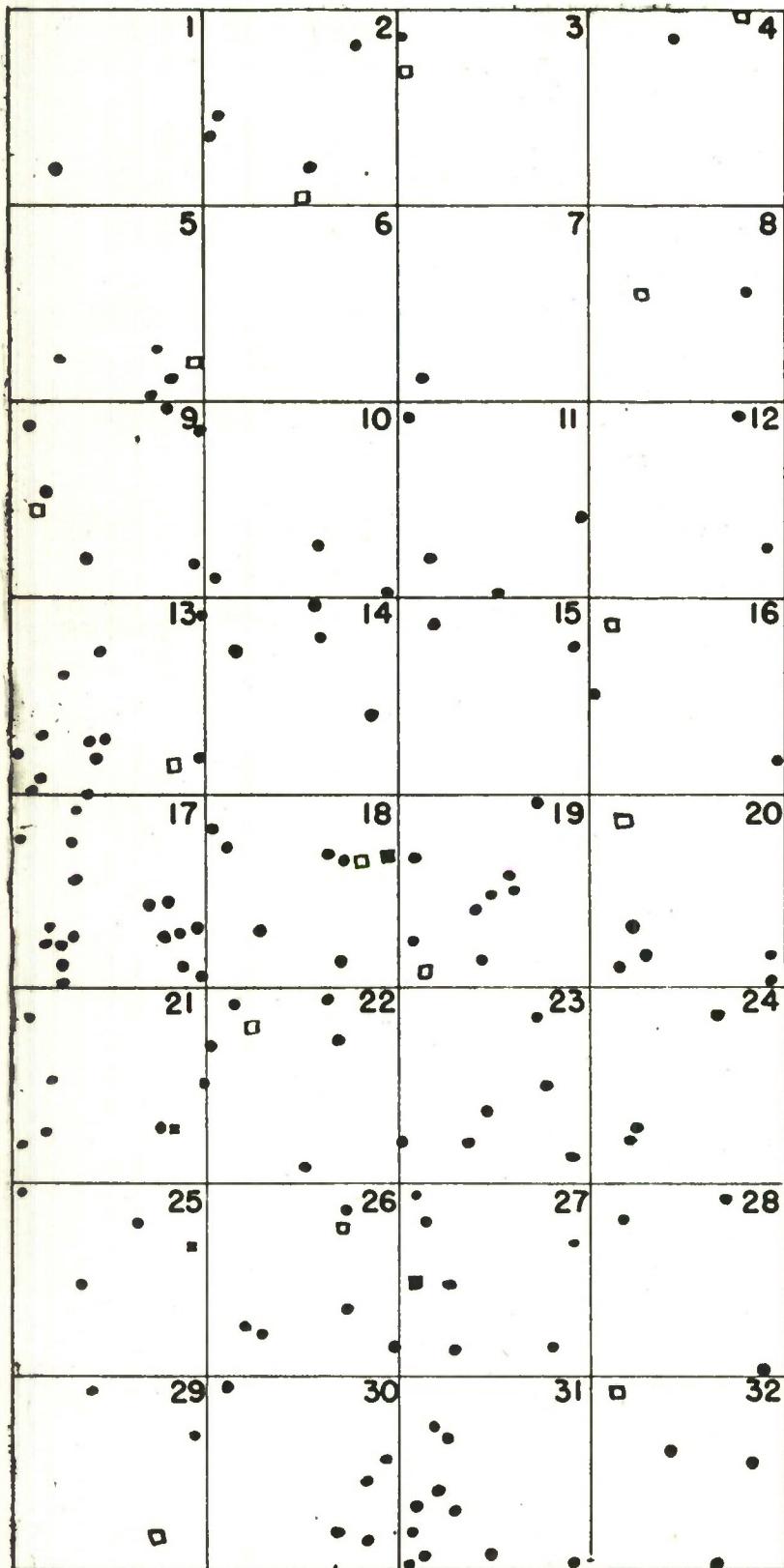
TOTAL NO. " "

" "

PLATE NO. 5

~~CONFIDENTIAL~~

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WARHEAD XM5E3

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 15

■ - CUBE PENETRATIONS
TOTAL NO. = 1

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 144

ZONE -

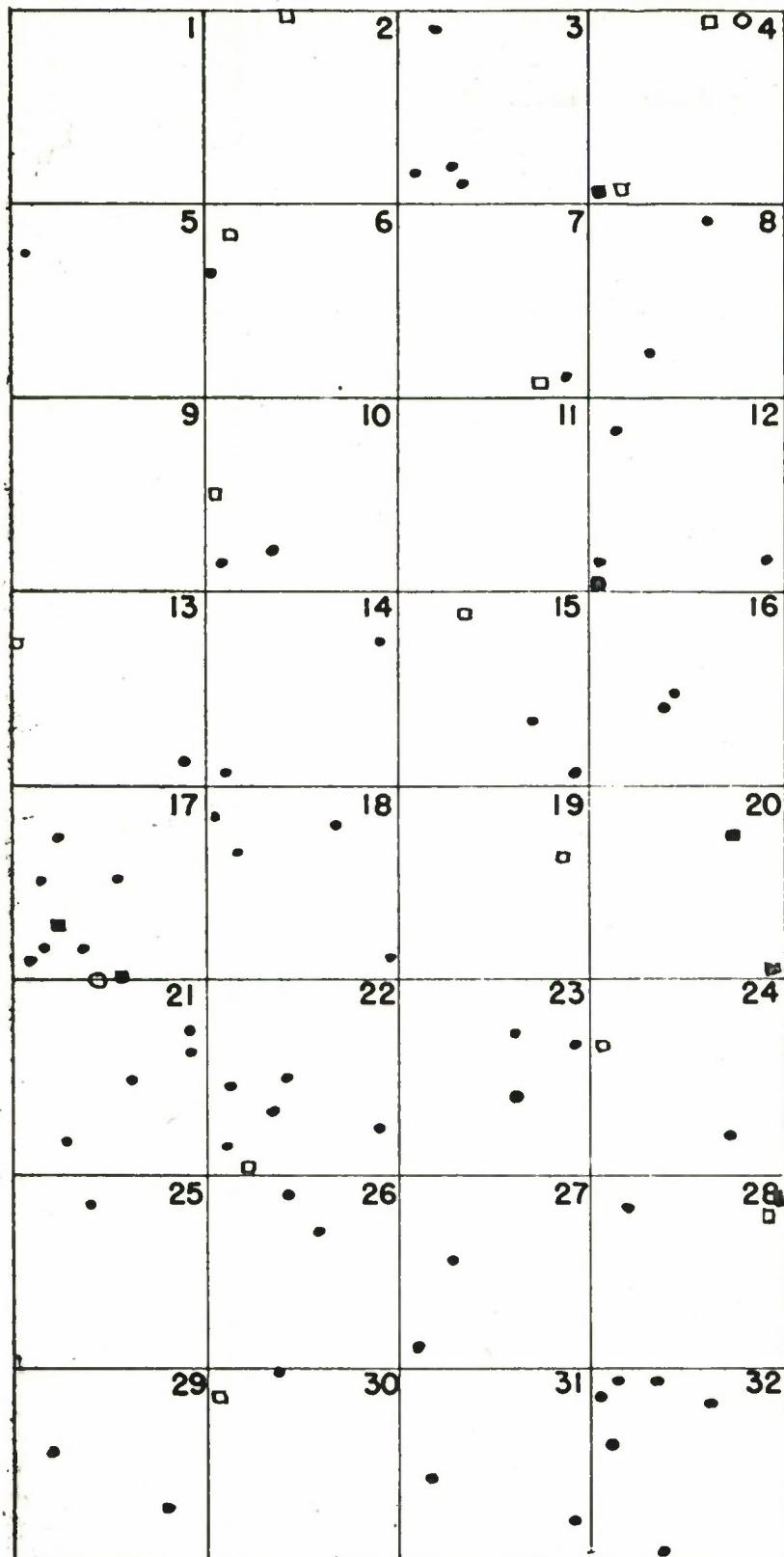
TOTAL NO. " "

" "

PLATE NO. 6

~~CONFIDENTIAL~~

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WARHEAD, XM5E3

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 13

● - CUBE PENETRATIONS
TOTAL NO. = 6

○ - OTHER PERFORATIONS
TOTAL NO. = 2

■ - OTHER PENETRATIONS
TOTAL NO. = 63

ZONE -

TOTAL NO. " " .
" " .

PLATE NO. 7

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16
17	18	19	20
21	22	23	24
25	26	27	28
29	30	31	32

WARHEAD ~~IM5E3~~

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 1

■ - CUBE PENETRATIONS
TOTAL NO. = 0

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 31

ZONE -

TOTAL NO. " " "
" " "

PLATE NO. 8

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16
17	18	19	20
21	22	23	24
25	26	27	28
29	30	31	32

WARHEAD XM5E3

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 3

■ - CUBE PENETRATIONS
TOTAL NO. = 1

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 45

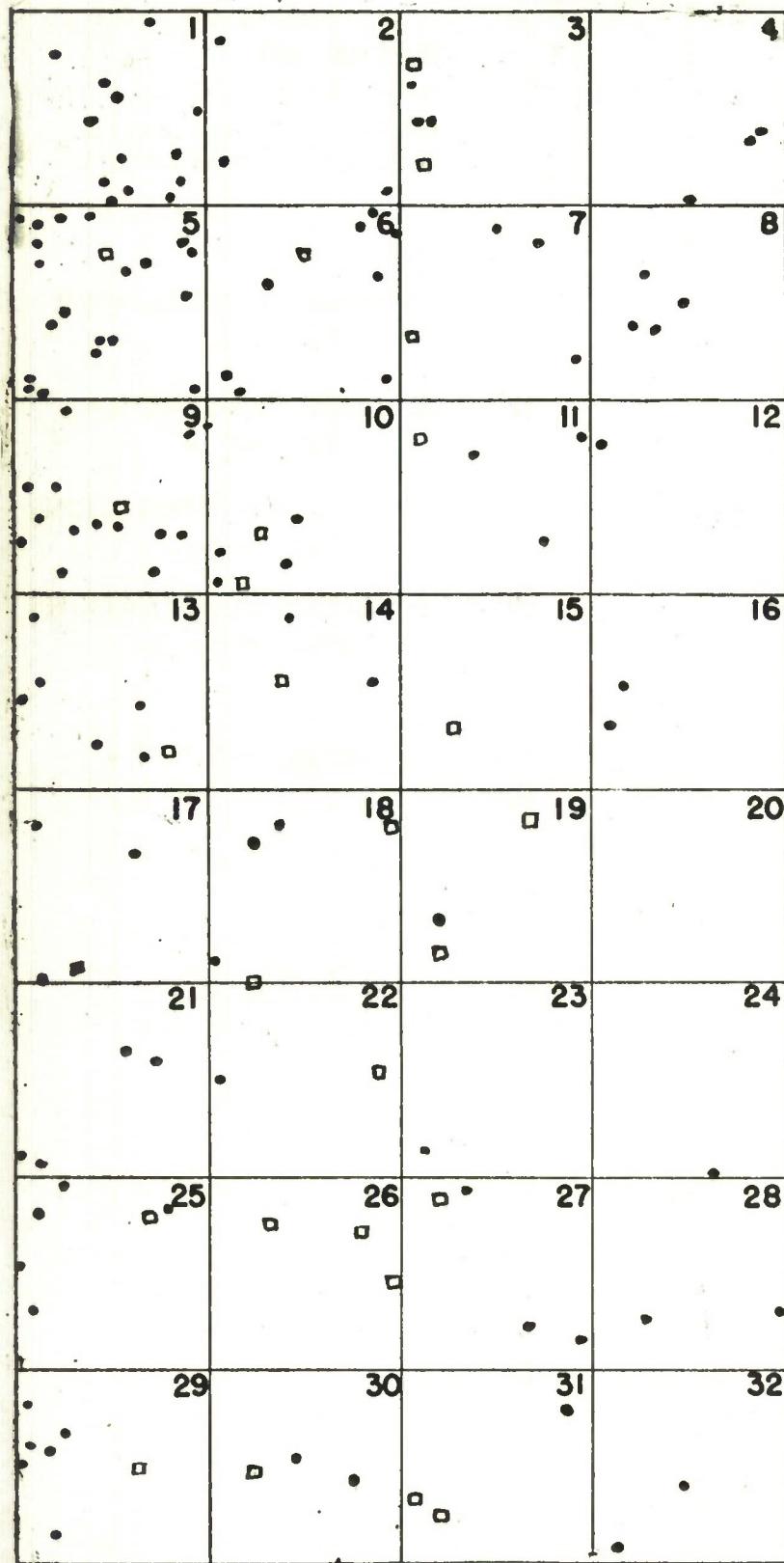
ZONE -

TOTAL NO. " " "
" " "

PLATE NO. A

~~CONFIDENTIAL~~

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WARHEAD XME3

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 26

■ - CUBE PENETRATIONS
TOTAL NO. = 1

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 124

ZONE -

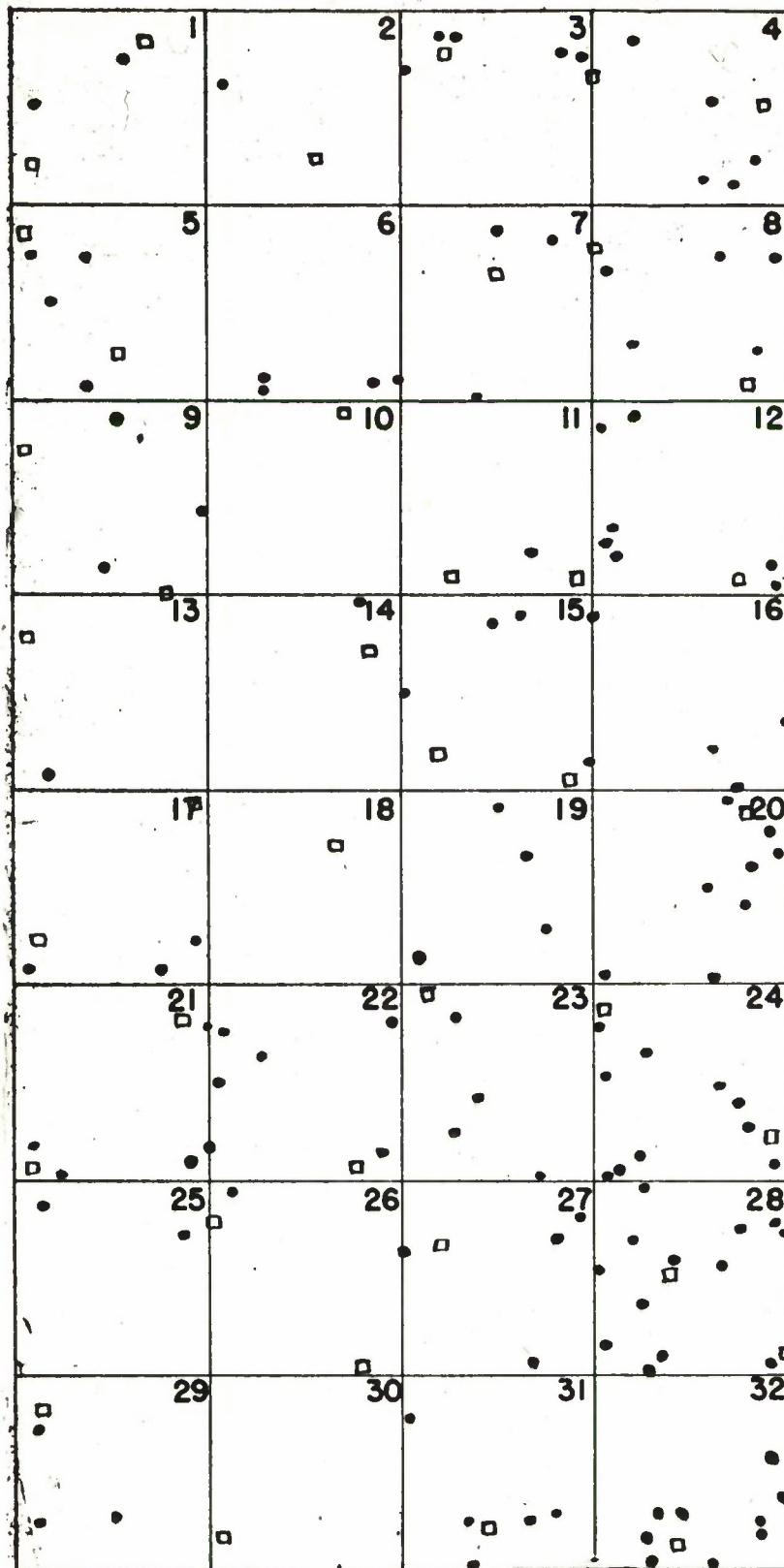
TOTAL NO. " "

" "

PLATE NO. B

~~CONFIDENTIAL~~

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WARHEAD XM5E3

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 39

■ - CUBE PENETRATIONS
TOTAL NO. = 0

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 127

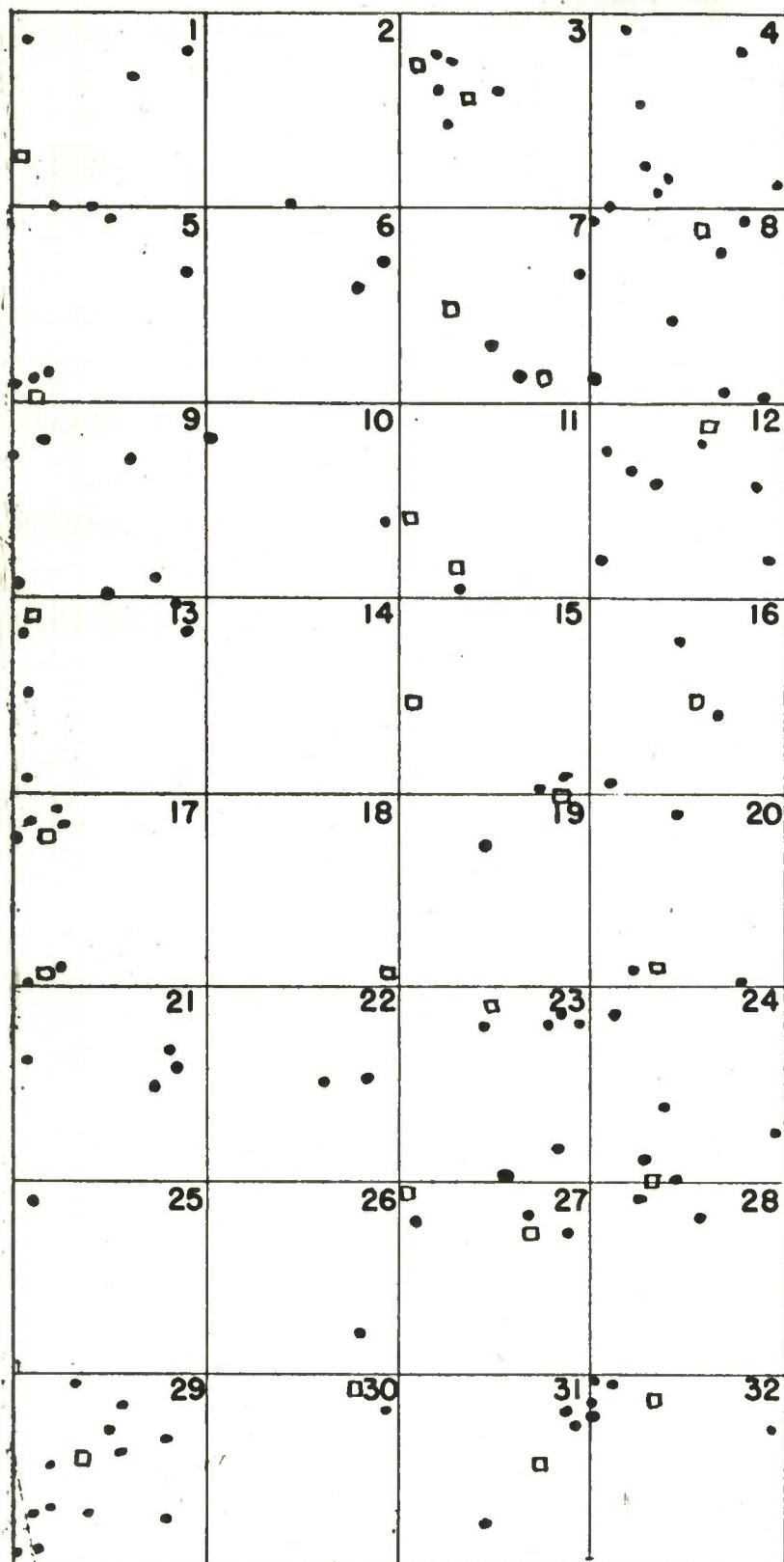
ZONE -

TOTAL NO. " " .
" " .

PLATE NO. C

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD XM5E3

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959

SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 26

■ - CUBE PENETRATIONS
TOTAL NO. = 0

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 118

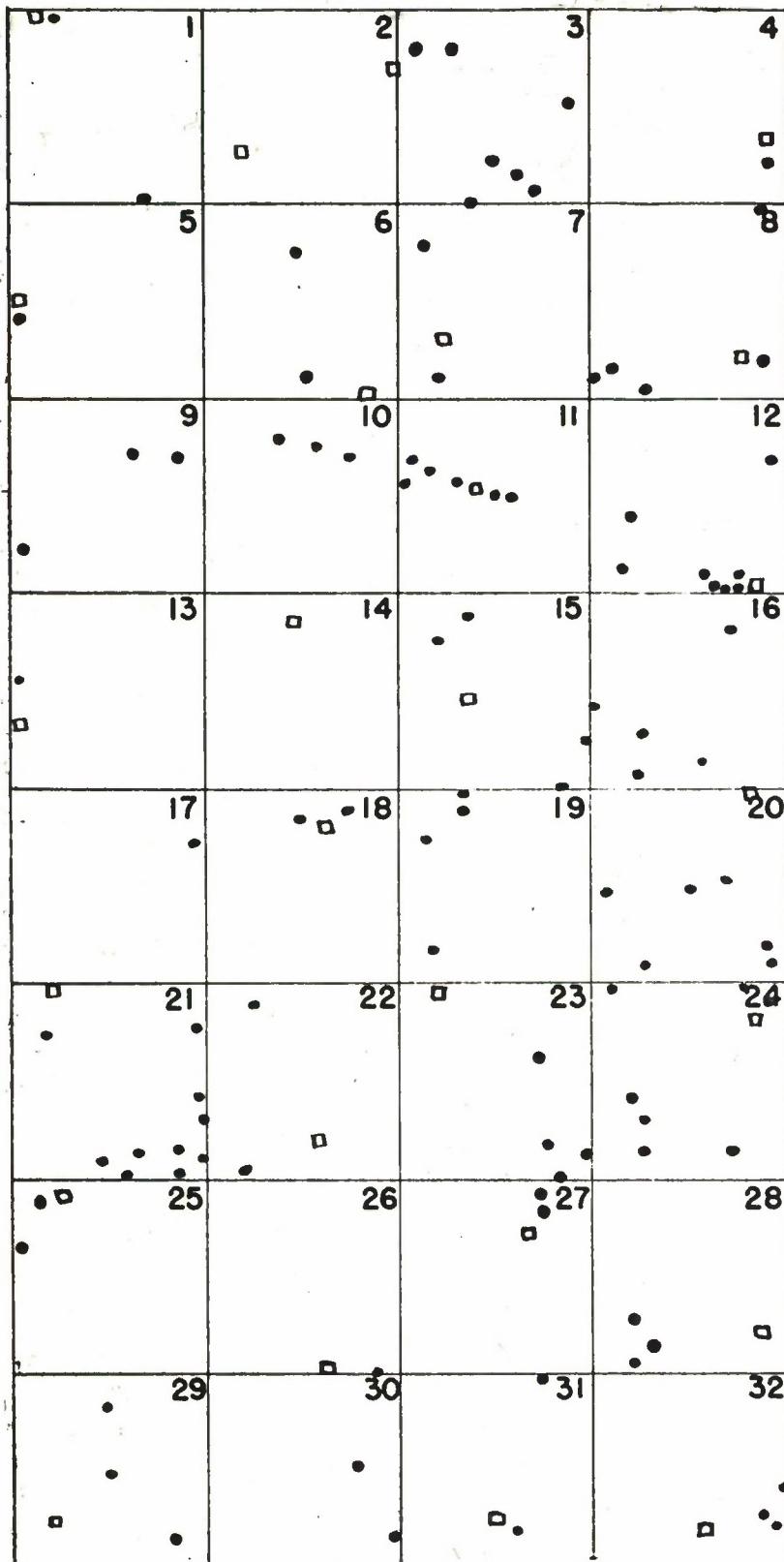
ZONE -

TOTAL NO. " " "
" " "

PLATE NO. D

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD , XM5E3

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959

SCALE 1 INCH = 1 FOOT



CODE :

□ - CUBE PERFORATIONS
TOTAL NO. = 26

■ - CUBE PENETRATIONS
TOTAL NO. = 0

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 103

ZONE -

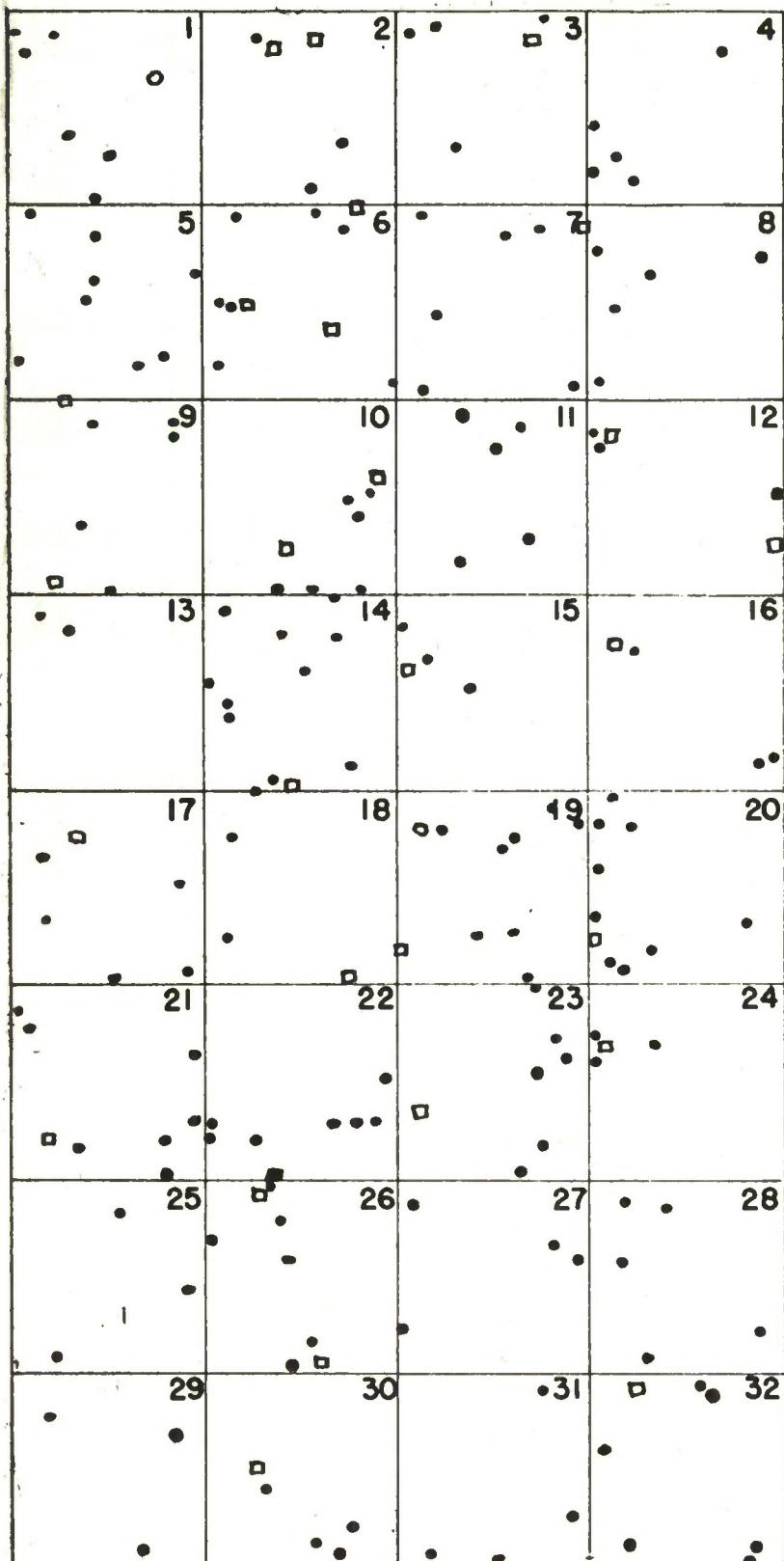
TOTAL NO. " "

" "

PLATE NO. E

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WARHEAD XM5E3

ROUND NO. 2

UNIT NO. 16

DATE 6 October 1959
SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 28

■ - CUBE PENETRATIONS
TOTAL NO. = 1

○ - OTHER PERFORATIONS
TOTAL NO. = 1

● - OTHER PENETRATIONS
TOTAL NO. = 165

ZONE -

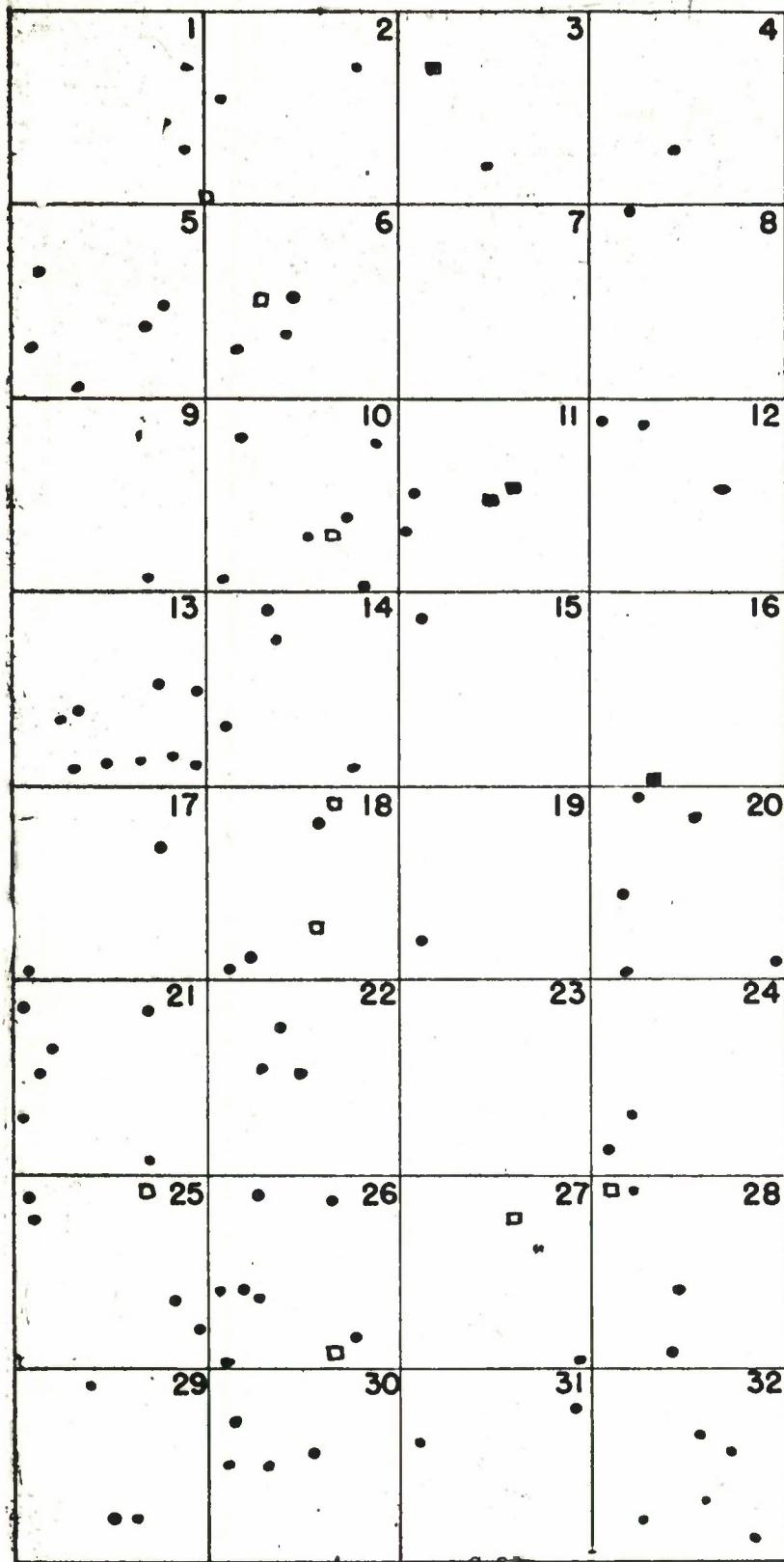
TOTAL NO. " "

" "

PLATE NO. F

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



WARHEAD XM5E3
ROUND NO. 2
UNIT NO. 16
DATE 6 October 1959
SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
TOTAL NO. = 9

■ - CUBE PENETRATIONS
TOTAL NO. = 4

○ - OTHER PERFORATIONS
TOTAL NO. = 0

● - OTHER PENETRATIONS
TOTAL NO. = 94

ZONE -

TOTAL NO. " " =

" " =

PLATE NO. G

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1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16
17	18	19	20
21	22	23	24
25	26	27	28
29	30	31	32

WARHEAD ~~XN5E3~~
 ROUND NO. 2
 UNIT NO. 16
 DATE 6 October 1959
 SCALE 1 INCH = 1 FOOT



CODE:

□ - CUBE PERFORATIONS
 TOTAL NO. = 1

■ - CUBE PENETRATIONS
 TOTAL NO. = 0

○ - OTHER PERFORATIONS
 TOTAL NO. = 0

● - OTHER PENETRATIONS
 TOTAL NO. = 49

ZONE -

TOTAL NO. " "

" "

PLATE NO. 1

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APPENDIX D

Analytical Laboratory Report 59-AL-153
18 November 1959

Title: Fragmentation and Drop Test of Warhead XM5E3

Project No.: PA-I/58/D77

Prepared for: Bomb & Fragmentation Branch, Inf & Acft Wpns Div

INTRODUCTION

(C) Static detonation of two XM5E3 Warheads was conducted to obtain blast and fragment data for two warhead orientations. The warhead longitudinal axis was parallel to the ground for each of the detonations. The position of the fuze cavity, which was on top for the first detonation, was rotated 90° from the original position for the second detonation.

(U) This report presents and evaluates the pressure data obtained for each of the two detonations.

INSTRUMENTATION

(U) Two types of instrumentation, one photographic and the other electronic, were used to obtain blast data. The photographic technique, referred to as the "fence" technique, is relatively new and therefore described in some detail. Location and orientation of the various instruments used to record blast are shown in Figure 2, inclosed. This arrangement is a slight modification of the original test plan presented in Inclosure 1.

Pressure Transducers

(U) Crystal pressure transducers were used to record blast pressure as a function of time at two gage locations, identified as A and B in Figure 2. Output of the transducers was recorded on 35-mm film from which peak overpressure and shock wave velocity were derived.

(U) Calibration of three pressure gages positioned at each location was accomplished by spanning the gages with a pair of velocity gages which recorded arrival times of the shock wave. Velocity of the shock wave was computed from the arrival times and converted to pressure by use of the Rankine-Hugoniot equation which expresses pressure as a function of velocity. A gage constant was then found by relating the pressure derived from velocity to measurements of the pressure trace of the respective transducer in terms of calibration deflection.

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Fence Method

The fence technique was used locally in but one other test, and in that test, pressure levels were about 10% of those anticipated from the XM5E3 warhead. Therefore, higher camera speeds were required (See Incl 1). This technique was included to supplement the usual instrumentation (pressure and velocity gages) because erratic pressure-time histories had been obtained on previous testing of this type warhead.

A fence consisting of equally spaced vertical divisions (called poles) is photographed by Fastax cameras during the passing of the shock front. Light waves passing from undisturbed air to the turbulent region immediately behind the front undergo an abrupt change in direction. This phenomenon appears on the film as distortion or deletion of successive fence poles as the front moves away from the point of detonation.

Three fences, one 8 feet and two 4 feet long, and subdivided into 3-inch alternating black and white vertical stripes, were placed as shown in Figure 2. Two 16-mm Fastax cameras, one of which was half-framed, were employed. The line of sight of the half-framed camera was perpendicular to the midpoint of the 8-foot fence, while the line of sight from the other camera was perpendicular to the edge (nearest the warhead) of the first 4-foot fence.

COMPUTATIONS

The Rankine-Hugoniot equation was used to compute peak overpressure from velocities obtained with velocity pickup gages during both the calibration and warhead detonations. Shock velocities computed from the fence technique were also converted to pressure by use of this equation.

$$P_s = P_0 \left(\frac{2\gamma}{\gamma + 1} \right) \left[\left(\frac{V + K}{V_0} \right)^2 - 1 \right]$$

Where:

P_s = peak overpressure (psi)

P_0 = local atmospheric pressure (psi)

γ = specific heats for air (1.4)

V = velocity of shock wave (fps)

K = correction for effect of wind, taken for each detonation (fps)

V_0 = local of speed of sound (fps)

A gage constant was calculated for each pressure gage on each calibration detonation in the following manner

$$K_a = \frac{c v k}{(D_p)(D_c)}$$

where

K_a = gage constant ($\mu Q/\text{psi}$)

c = calibrating capacitance (μf)

v = voltage (0.1 volts)

k = peak deflection measurement

D_p = peak deflection from shock velocity (psi)

D_c = calibration deflection measurement

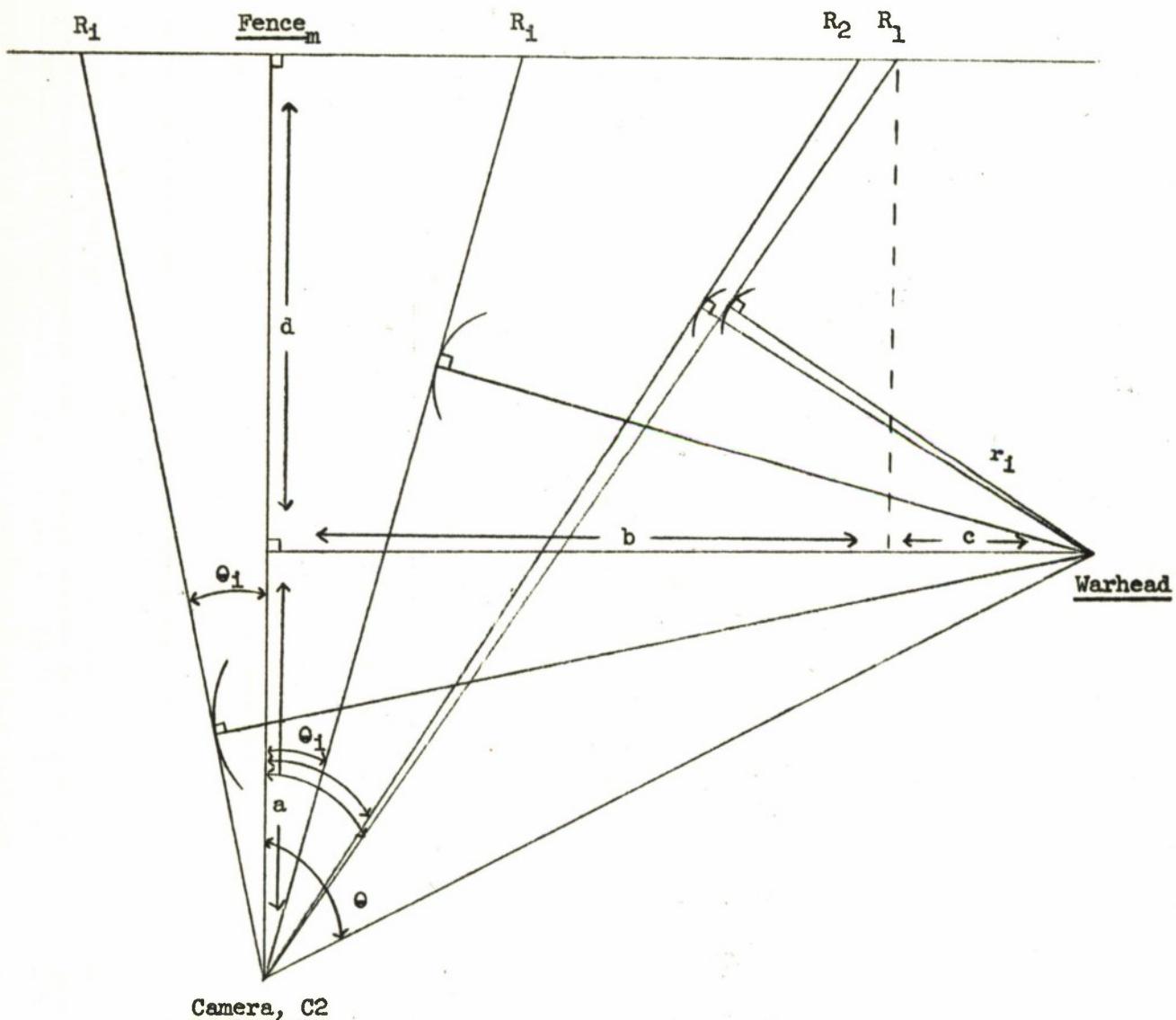
Shock velocities are normally obtained from the fence technique in the following manner. Figure 1, illustrates the field setup for the fence technique computation for the 16-mm full-frame camera. The distances are not scaled, as the sketch is intended only as a guide for following the velocity computations.

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Figure 1
Field Set-Up
for
Fence Velocity Method



a, b, c, d: Defined in diagram

R_1 = pole distance from R_1

r_1 = radius of shock wave at t_1

t_1 = arrival time of shock wave at r_1 D-4

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$$\theta = \tan^{-1} \left(\frac{b+c}{a} \right); \quad \theta_i = \tan^{-1} \left(\frac{b-R_i}{a+d} \right) \text{ for } i \leq m$$

$$\theta_i = \tan^{-1} \left(\frac{b+R_i}{a+d} \right) \text{ for } i \geq m$$

$$r_i = h \sin(\theta - \theta_i) \text{ for } i \leq m$$

$$r_i = h \sin(\theta + \theta_i) \text{ for } i \geq m$$

$$\Delta r_i = r_i - r_{i-1}$$

$$\bar{v}_i = \frac{\Delta r_i}{\Delta t_i} = \frac{r_i - r_{i-1}}{t_i - t_{i-1}} \quad \bar{v}_i = \text{average velocity}$$

$$r'_i = 1/2 (r_i + r_{i-1})$$

r'_i = radius of shock at \bar{v}_i

(U) The above method could not be directly applied to this test because of interference of an unexpected jet front which developed (See discussion in Results), preventing measurements needed for accurate calculation of the radii, r_i and Δr_i . It was possible, however, to estimate Δr_i with reasonable accuracy directly from the Fastax film. The movement (in units) of the shock front between successive frames was measured on the film and calibrated by a film constant (ft per unit) to obtain Δr_i (ft). The use of linear film constant introduced a bias into the Δr_i . The effect of this bias is discussed in the results.

RESULTS

(C) Examination of the film records showed that a jet probably consisting of extremely hot gases and burning particles of explosive was emitted in the direction of the gage stands immediately after detonation. The center of this

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moving mass was located half way up the fence, 10 feet above the ground, at about the same height as the gage cluster (See Figure 3). The brightness of the jet overexposed the portions of the film immediately bordering the jet front, thereby preventing accurate reduction of its velocity as a function of fence distance. However, it was possible to estimate velocity of the jet from the first few frames in which the front silhouetted the beginning of the 8-foot fence. This velocity was between 2500-3000 fps. The jet stream slowed down considerably before traveling the 12-foot distance to the beginning of the first 4-foot fence.

(C) Formation of a shock front was not evident on the film until the jet front had traversed the 8-foot fence. At this time, a shock wave began forming in the top and bottom quarter of the fence at approximately the beginning of the fence. (The 20-foot height of the fence was divided, vertically, into four sections by horizontal cross bars.) In other words, the formation of a shock wave trailed the jet front by 6 to 8 feet, but as the front moved away from the detonation, shock wave formation became clearer.

(C) Initially, the slope of the wave was quite sharp, making a 30° to 40° angle with the horizontal. As the wave moved laterally away from the beginning of the 8-foot fence, this angle increased, until, at some greater distance, the shock wave would appear perpendicular to the horizontal. This results because the detonation of the warhead emits, for all practical purposes, a spherical shock front. As the diameter of the sphere increases, the curvature of the arc which is seen against the targets decreases.

(C) Photographs of the second detonation (Figure 3) show the sequence of events mentioned above. A second shock front, opposite in orientation to the first, is also visible. This is the reflected wave (initial wave reflected off the ground) which eventually overtakes and joins the initial wave some distance beyond the fences.

(C) Pressure data obtained from each of the three methods employed for the two warhead detonations are presented in Tables I and II. A discussion of the measurements and an evaluation of the data follow the tabular presentation.

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(c) Pressure and Velocity Gages

Table I. Peak Pressure, psi, Derived from Pressure and Velocity Gages

<u>Gage Location</u>	<u>Gage, and Position on Gage Stand</u>	<u>Detonation 1</u>	<u>Detonation 2</u>
A	Velocity	74.5	92.3
	Pressure (top)	7.2	18.8
	Pressure (center)	27.3	22.0
	Pressure (bottom)	29.2	20.5
B	Velocity	58.2	110.7
	Pressure (top)	20.2	19.5
	Pressure (center)	38.3	19.2
	Pressure (bottom)	34.1	18.6

(c) The pressure traces for all pressure gages at position A were erratic and oscillatory. It is quite probable that this position was engulfed by flame or heat at about the time the shock wave arrived. The crystals used in these pressure transducers react adversely to heat. Except for the values obtained from the top pressure gages for detonation 1, there appears to be good agreement among pressures, by position.

(c) The pressures computed from velocity gages are not valid. As discussed above, the shock front did not traverse the pair of velocity pick-up gages normally, i.e., the shock wave did not move as a plane normal to the line joining the gages. The difference between times of arrival at the two gages did not correspond to the travel distance of the shock front equal to that distance between gages. Unfortunately the actual travel could not be computed from the Fastax film because the shock front in the vicinity of the velocity gages was obscured by the jet. Pressures computed from the velocity records have been included, however, to point out the pitfall of accepting data on the basis of film records of velocity.

(c) Fence

Table II. Pressure, psi, derived by the Fence Technique

<u>Detonation No. 1</u>		<u>Detonation No. 2</u>	
<u>Time, ms</u>	<u>Pressure, psi</u>	<u>Time, ms</u>	<u>Pressure, psi</u>
<u>16-mm</u>	<u>16-mm</u>	<u>8-mm</u>	<u>8-mm</u>
		6.46	45.0
		6.93	32.3
5.43	35.0	7.39	32.3
5.89	41.3	7.85	27.6
6.35	35.9	9.80	17.6
6.81	28.9	10.31	15.8
		10.82	12.5
		11.33	13.3
		14.64	10.9
		15.15	7.7
		15.66	2.7
		16.16	5.6
		16.67	6.3

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(C) Pressure data from the fence technique is very limited for detonation No. 1. Lack of sunlight because of cloudy and overcast sky at the time of this detonation reduced the number of observations available from the Fastax film. No shock wave refraction was discernible for the 8-mm film and only a few values were obtained at the beginning of the fence from the 16-mm film. Observations were available from both the 8-mm and 16-mm film for the second detonation. The agreement of pressure values between these cameras is very good.

(C) The fences were constructed so that the center of the fence would be at the same height as the center of the warhead. This was accomplished so that first observations of shock arrival for each pole would appear at the middle of the fence. However, as the jet front and flame prevented observation of the arrival of the shock as a function of distance, it was preferable to present overpressure data as a function of time rather than distance. In this computation (see "computations" above) the selection of a linear constant would cause an error of about 7% in velocity data measured near the start of the fence and slightly higher farther along the fence. This would correspond to about an error of 8 psi on the high side where the calculated pressure was 40 psi and 7 psi where the calculated pressure was 20 psi. However, in view of the approximate nature of the velocity data, no actual correction was made to the results appearing in Table II.

(C) Evaluation of Results

(C) A question now arises as to the validity of data obtained with the pressure transducers because of differences in pressure levels between the two detonations. It will be shown that the pressure obtained from the fence technique and those measured with gages on the first test closely approximates computed theoretical pressures for the XM5E3 warhead.

(C) It is not known to what degree the jet front enveloped and affected the pressure gages, but it is suspected that the difference in pressure level between the two detonations is affected more by the jet stream than warhead orientation. It is not conceivable that a 90° difference in fuze cavity orientation would cause a halving of pressure the same distance for the warhead. Additionally, the center of the jet mass was moving down the center of the fence for the first detonation and several inches above the center for the second detonation.

(C) The effective weight of propellant in the warhead in pounds of spherical pentolite was computed using technical data promulgated in NAVORD Report No. 2753. This computation shows the propellant in the warhead can be represented by 53 pounds of pentolite. Peak overpressure 20 feet from a detonation of 53 pounds of spherical pentolite would be 29 psi. It is shown below that

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the fence data justifies this value and that the propagation of the blast wave from the warhead was similar to that expected from theoretical considerations.

(C) Considerable testing has been accomplished for static detonation of bare spherical charges of pentolite. These data have been summarized in the form of graphs expressing pressure as a function of arrival time of shock wave. Theoretical pressures were computed over a time interval spanning the observations obtained from all fence data from both detonations, using 53 pounds of spherical pentolite as the equivalent weight for the warhead detonation. For comparison, both theoretical and observed fence pressure were plotted as a function of time in the enclosed chart. It is interesting to note that at $t = 5.6$ ms, the arrival time corresponding to a distance of 20 feet, the pressure from the fence data is 12 psi greater than the theoretical pressure. In the preceding discussion it was mentioned that selection of a linear constant would result in an error of about 8 psi on the high side at a calculated pressure around 40 psi. Thus a pressure of about 30 psi at a distance of 20 feet from the detonation appears reasonable from theoretical calculations backed up by evidence from the fence data. Pressures measured for detonation No. 1 were in this order.

CONCLUSION

(C) The fence technique indicates blast pressure 20 feet from the detonation of Warhead, XM5E3, is about 30 psi. The data evolved from the pressure gages were influenced by their particular orientation with respect to the jet stream. If measurements could be made 20 feet from the detonation at locations other than the area of the jet stream, the pressure expected would be in the order of 30 psi.

RECOMMENDATION

(C) In future detonations of the XM5E3 Warhead, blast measurements should be made at distances greater than 20 feet, or at a distance beyond the jet front. Having made accurate pressure determinations at a given distance, additional pressure values can then be calculated for other desired distances.

(C) The fence velocity technique should be used in addition to pressure transducers to obtain blast data for all future testing of XM5E3 Warhead. This is the second occasion, in as many tests, that the technique has been

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usefully employed. In addition to obtaining pressure data, the technique allowed observations of the jet front which were heretofore not available.

SUBMITTED:

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REVIEWED:

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Engineering Laboratories
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APPROVED:

A. E. Karp
A. E. KARP, Chief
Analytical Laboratory

Inclosures:

1. Test Plan
2. Gage and Fence Orientation Chart
3. Photograph of Shock Wave (See page 21, figure 16 of this report)
4. Pressure vs Time Chart

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W
Mr. W Kokinakis/mwb/31163
29 July 1959

THRU : *JH* Chief, Analytical Laboratory

TO : Chief, Bomb & Fragmentation Branch, I&AW Div

FROM : Chief, Mathematics Section, Analytical Laboratory

SUBJECT: Test Plan - XM5 Warhead Static Detonation

(U) 1. This test was initiated to obtain information about the blast and fragmentation characteristics of the XM5 Warhead. The instrumental setup and test procedure outlined herein pertain only to the blast portion of the test. No interference is foreseen between these requirements and requirements relating to the fragmentation portion of the test.

(C) 2. Two warheads will be detonated, one placed with its longitudinal axis parallel to the ground, and the other with its longitudinal axis perpendicular to the ground. As requested in the test directive, blast will be measured at two positions 20 feet from the center of the warhead. Gages will be placed at positions 15° on either side of the projection of the longitudinal axis for the warhead placed parallel to the ground, hereafter referred to as Line A. Gages will remain at the same positions for the detonation of the other warhead. It is recommended that blast measurements be accomplished by two methods; a) with pressure transducers and velocity pickup gages, and b) a new method, employing Fastax cameras, referred to as the "fence-velocity" technique.

(C) 3. Blast Pressure Transducers:

a. Two stands, each supporting two pressure gages and a pair of velocity pickup gages, will be positioned approximately 22 feet from the center of the warhead. The center of the sensing element of the pressure gages should be 20 feet from the center of the charge and the velocity span should be between 3 and 5 feet. Free air measurements are to be realized, and as the center of the warhead is 10 feet above the ground, the pressure transducers should also be about 10 feet above the ground. Frag poles should be used to protect the instruments from flying debris during the warhead detonation. It is anticipated that peak over pressure will be about 36 psi and shock velocity 2000 fps in the vicinity of the pressure transducers.

(U) 4. Fence Velocity Technique:

a. The blast wave emitted from the detonation will be photographed by two Fastax cameras, 280 feet from Line A. The shock wave will be photographed with the aid of three fences, 20 feet beyond and parallel to Line A. All fences will be 20 feet high, with one 8 feet and the other two 4 feet wide. See inclosed diagram for fence design and detailed measurements.

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Subject: Test Plan - XM5 Warhead Static Detonation

29 July 1959

b. A distance greater than 300 feet between camera locations and fence is desirable, but the terrain at the test site limits the choice of distance. 8-mm and 16-mm cameras, both equipped with 4-inch lenses, should be utilized for photographing the shock front. The line of sight for the 8-mm, C-1, should be perpendicular to the 8-foot fence at the midpoint. This camera should be tilted 90° about the optic axis to allow full fence coverage, 30 feet vertically and 11.25 feet horizontally. The line of sight for the 16-mm camera, C-2, should be perpendicular to the first 4-foot fence at the edge nearest the warhead. This camera will cover all fences, both vertically and horizontally. Both cameras should be oriented such that the optic axis will be approximately 10 feet above the ground at the target. Approximate framing rate desired is 10,000 frames per second for the 8-mm and 5000 frames per second for the 16-mm. Both cameras should be started by the sequence timer and allowed to attain nominal framing rate before shock wave arrival. As the time during which the cameras are viewing the effect of shock wave on the fence is small, as much as 80% of the film can be expended (80 of 100 feet) before detonation occurs.

5. Calibration:

a. Five 20-pound charges of spherical pentolite should be made available for gage calibration and camera checkout. The center of each charge should be placed 10 feet above the ground along Line A, and 13 feet from the center of the blast gages. Fastax coverage will also be provided during the gage calibration phase. It is recommended that not more than two charges be detonated on the first day and that the film be processed and submitted to the Analytical Laboratory for study before any additional charges are detonated. Upon completion of investigation of the first two rounds, this Laboratory will recommend changes if necessary to improve data acquisition.

b. Two additional charges should then be detonated prior to the warhead detonation. The fifth calibration charge should be detonated immediately after the second warhead detonation. Fastax coverage should not be necessary during this last calibration detonation.

c. Two extra pressure transducers, in addition to the four to be used during the test, should be calibrated with the bare spherical charges. Since there is a chance of gage damage on the first warhead detonation from fragments, spare gages should be available for the second warhead.

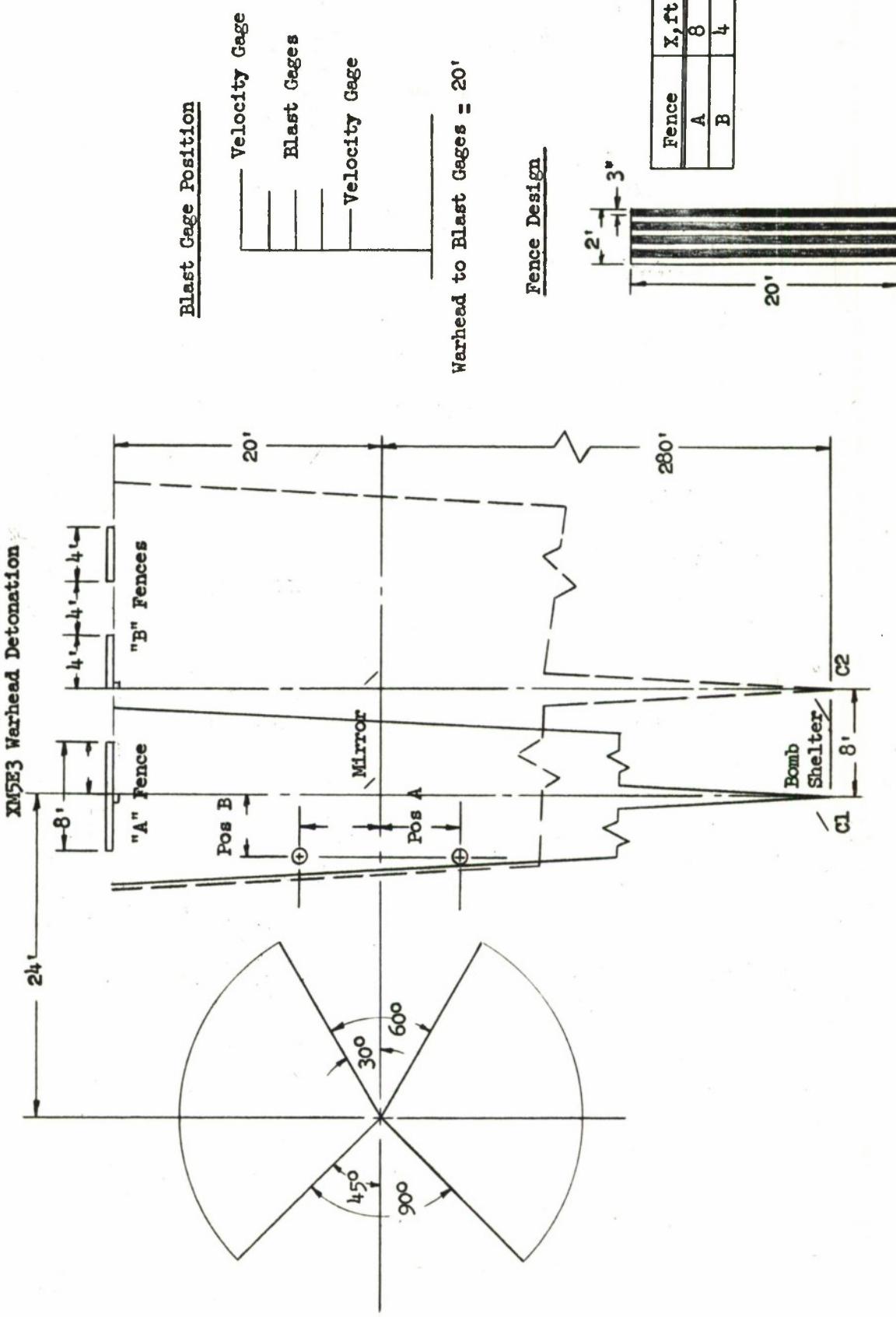
Incl 1


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Figure 2
Blast Gage, Camera and Fence Location
for
XME3 Warhead Detonation



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Chart

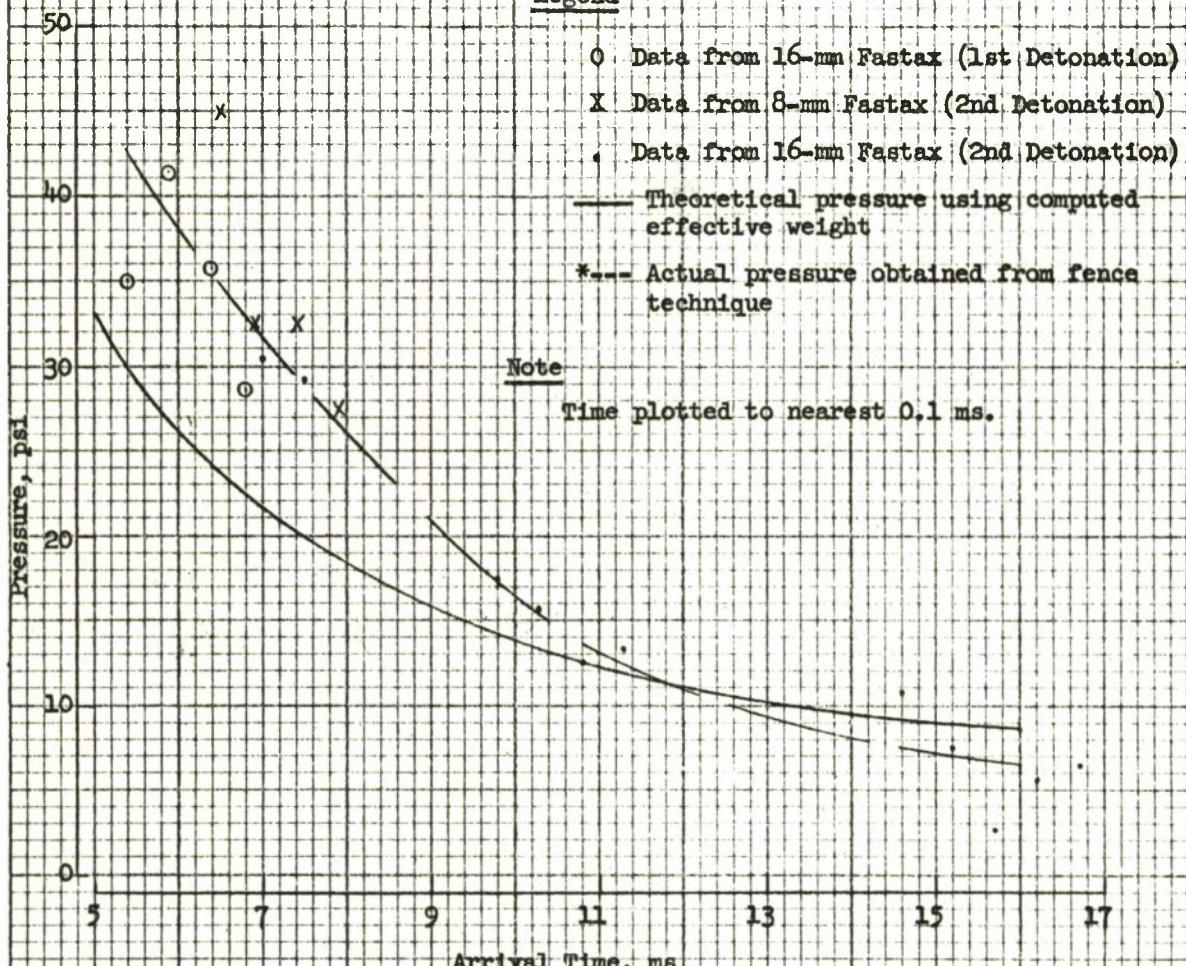
of

Pressure vs Time

for

XM5E3 Warhead Static Detonation

Legend



Note

Time plotted to nearest 0.1 ms.

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APPENDIX E

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